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The impact of a SmartLab implementation on rural schools in North Dakota

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The impact of a SmartLab® implementation on rural schools in North Dakota

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THE IMPACT OF A SMARTLAB® IMPLEMENTATION ON

RURAL SCHOOLS IN NORTH DAKOTA

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DEDICATION

This dissertation is dedicated to the memory of my father. He was so proud that I was pursuing a higher education and supported me as much as he could. He loved me unconditionally and would have been so proud to see me complete this journey. His loss in February 2020 was sudden and traumatic, but I know he would have wanted me to push through the pain and finish, even if he would not be there to watch me walk across the stage. This dissertation and ultimate culmination of this degree is dedicated in his honor. I love you dad.

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NOMENCLATURE

NDCDE	North Dakota Center for Distance Education
CLS	Creative Learning Systems
CLE	Constructivist Learning Environment
ISTE	International Standards of Technology Education
OAIC	Orchestrated Immersion in Complex Experience
DLA	Digital Literacy Assessment
FACILITATORS	Teachers in the SmartLab®

ACKNOWLEDGMENTS

I would like to acknowledge all the people that contributed to my ability to complete this study. First, I would like to acknowledge my family, my husband Kenny, my daughters Faith and Jasmine and my son Caleb. Thank you for your patience and support throughout this entire journey. It has not always been easy, and I know that my absence and stress was felt on many levels over the past few years, thank you for believing in me and for continuing to encourage me, even when I felt that things were bleak. I hope you know you all are my inspiration for this journey.

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ABSTRACT

This mixed methods quasi-experimental phenomenological study investigated the impact that a SmartLab® implementation had on four rural schools in the state of North Dakota. This study featured semi structured interview questions for facilitators, semi-structured focus group questions for students, and a digital literacy pre and post assessment (DLA) that was administered to students. This study looked at student learning in terms of twenty-first century skills, teacher and student perspectives in terms of student learning as well as teacher perspectives on the impact of the SmartLab® on their own teaching methods.

Two facilitators from two of the four schools were interviewed in the fall of 2018 and again in the spring of 2019 and two student focus groups were conducted in the spring 2019. The DLA pre assessment was administered in the fall of 2018 and the post assessment was administered in the spring of 2019 at all four schools to measure any notable change in scores. A review of the literature focused on the constructivist learning theory, characteristics of successful teaching models, CLEs, constructivist teacher methods, and student learning in terms of twenty-first century skills.

Data revealed in this study indicated that there was a significant impact on student learning as a result of SmartLab® implementation as evident by focus group results, teacher interviews, as well as pre and post exam scores from the DLA. Furthermore, there were also reported impacts on teacher methods as well as perceptions of increased opportunity, equity and impact on administration and community. Finally, it was reported that specified student needs were being met as a result of SmartLab® implementation.

CHAPTER 1. INTRODUCTION

Technology integration in rural schools can present a challenge as teacher shortages across the country and specifically in the state of North Dakota continue to climb. In 2018, the North Dakota education standards and practices board (ESPB, 2018) reported a critical teacher shortage in all areas in the state. A deficiency in teacher candidates, especially in rural areas of the state, can limit the opportunities for students from those areas, as schools are unable to offer advanced classes, and may struggle to implement unfamiliar or new technology. Schools will often support technology enhanced learning but underestimate the difficulty of the implementation (Resta & Laferriere, 2015). Incorporating current technology into a school, and tasking teachers to develop curriculum, design assessments, projects and to provide overall support students in technology driven environments may be unrealistic and overburdening for many teachers. In addition and related to the teacher shortage issue in rural communities, is the funding differences between urban and rural schools. Malhoit (2005) found that due to a variety of issues such as geographic location, at-risk youth, and poverty, it is often more expensive to fund a rural school even with a lower population. In the state of North Dakota, funding is based on a per pupil basis. There are some adjustments made, however when rural schools funding is adjusted due to higher cost, it is often "not sufficient enough to reflect the higher costs" (Malhoit, 2005, p.4). The result is that rural schools do not have the same options to fund expensive technology-based initiatives. This difference further contributes to the digital divide that was identified by Resta and Laferriere (2015) as "differences between individuals, households, companies, or regions related to their access to and usage of information and communication technology" (p.745).

SmartLabs® are a turn-key, technology-based, student-centered environment that can

be integrated into any school. To be defined as turn-key, the SmartLab® environment includes computers, hardware, software, kits, curriculum, assessment templates, teacher training and technology support. This approach provides an option for schools to integrate technology, train existing teachers in a new methodology, and allows students the option for technology-based career exploration and the cultivation of twenty-first century skills. Creative Learning Systems, the developers of the SmartLabs®, describe the learning process that occurs:

> SmartLabs® require students to define goals and problems to solve using a variety of technologies. They need to think critically and creatively to accomplish this. Collaboration and communication with other students and the facilitator is part of the process. Various information sources and media may be used for research, production and presentation. Students are self-directed and self-assess through our ePortfolio system. Technology is applied as they follow a workflow to completion. Through it all, students acquire next generation skills that will be relevant and applicable for many years to come in through their college and career. (SmartLab STEM & Digital Media Arts Education. (Creative Learning Systems, n.d.)

A partnership was formed between the North Dakota state supported virtual school (NDCDE) and the developer of the SmartLabs® (Creative Learning Systems) to provide opportunity for North Dakota schools. This opportunity included installing labs at affordable rates and training local existing teachers or staff to be facilitators who, with support, and professional development, would be able to work effectively with students in the SmartLab® environment.

As technology continues to progress, so does the way information is shared. It is critical to level the playing field across the state to allow all students, regardless of where they live, the

opportunities and environments to develop skills that demand them to be more engaged in their own learning. SmartLab® environments shift the classroom into a student-centered project-based environment. A place where students are required to create goals, plan projects, and carry them out working with a partner using time management. The skills that students are practicing and building in SmartLab® environments have been referred to as twenty-first century skills or competencies, these skills have been identified as critical to the success of students in the future (Germaine, Richards, Koeller, & Schubert-Irastorza, 2016).

In 2016, North Dakota's governor was quoted as saying "We can't prepare our kids for the 21st century using a 19th-century model" (Office of Governor, State of North Dakota, 2016). Over the years, twenty-first century skills have been identified and defined in many ways. They have included the 4C's, communication, creativity, collaboration, and critical thinking (National Education Association, 2012), the P21 framework which includes critical thinking, problem solving, creativity and innovation, adaptability, collaboration, communication (written, oral, blended, advanced media), information sourcing and media literacy, self-direction and self-assessment, and application of technology to workflow (Frameworks & Resources, n.d). Husin et al. (2016) identified these skills as, digital age literacy, inventive thinking, effective communication, and high productivity. Considering all definitions or versions of twenty-first century skills, the most commonly accepted standards are those defined by the International Society for Technology in Education (ISTE) (Table 1). ISTE has defined what has become internationally recognized as the definition of twenty-first century skills or competencies. These competencies include, digital citizenship, knowledge construction, innovative designer, computational thinker, creative communicator, global collaborator, and empowered learner.

Table 1. *ISTE standards described with student competencies (Learning.com, 2018)*

Empowered Learner	Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences.
Digital Citizen	Students recognize the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, and they act and model in ways that are safe, legal and ethical.
Knowledge Constructor	Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.
Innovative Designer	Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.
Computational Thinker	Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.
Creative Communicator	Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.
Global Collaborator	Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.

"The ISTE standards serve as a framework for students, educators, administrators and coaches to rethink education and create innovative learning environments" (Robacker, 2019). To rethink education, there needs to be a consideration of how learning occurs. There may be difficulty in preparing students to use twenty-first century skills, if teachers are using a traditional teacher-centered model in a classroom. Barak (2017), specifically stated "…it

seems that today's teachers have an almost impossible task- to prepare students to become contributing citizens in a world that does not yet exist and cannot yet be clearly defined" (p. 286). Students will have careers that have yet to be defined and will need specific problem-solving skills that have not yet been clearly identified. It is therefore critical to find innovative ways and utilize the most effective models of teaching to educate students and help them to be prepared to learn how to learn.

Many teaching models exist and have been studied extensively, but among the more effective models, specific characteristics have been emphasized and deemed to contain the right attributes for learning to occur (Joyce, Weil & Calhoun, 2015). The common characteristics of the most effective models were identified by Joyce et. al., 2015 p. 7-9. These models include:

1. Helping students learn how to learn
    a. Including taking responsibility for learning
    b. Helping students go beyond where they are
2. Scaffolding for the Learning Process
    a. Helping students get over perceived limitations
3. Formative Assessments and Adjustments
4. Twenty-first century skills
5. Cultural Literacy and Global Awareness
6. Collaborative and Cooperative Skills
7. Creativity
    a. Convergent Thinking
8. A Constructivist Orientation

Examining the eight characteristics of effective models of teaching discussed it appears that the SmartLab® environment directly incorporates the characteristics of each of the effective models described by Joyce et. al. (2015). Each are described in more detail, to explain how the lab demonstrates the characteristic.

The first characteristic, helping students how to learn; including responsibility, is met by students in a SmartLab® as students are required to take ownership of their learning by formulating their own goals and documenting their learning process using journals. The second, in a SmartLab® the role of the teacher is shifted to that of a facilitator and their job is to guide the students and help them overcome obstacles while providing structure and support. Third, the facilitator also conducts formative assessment on an individual basis which is done through conversation and student demonstration in contrast to summative assessments. Fourth, as previously discussed, the SmartLab® environment is supportive of twenty-first century skill development where students collaborate, communicate, and can present or demonstrate knowledge creatively, this will be further discussed later. Fifth, many of the projects that students work through in a SmartLab® require research. Students must learn to investigate, and research not only locally, but throughout the world. They are also required to work with a partner as previously discussed, so cultural literacy in some cases is learned first-hand. Sixth, students must collaborate with each other and cooperate with one another to complete any/all projects they design. This in some cases can even extend to students working with one another at a distance to complete the activities that they have designed. Seventh, creativity is key in the SmartLab®, students must design and carry out projects that they design together. Not every project will be exactly the same. Students will create their goals together based on the interest they have on the topic. Finally, the SmartLab® can be defined as a Constructivist Learning

Environment (CLE). In a CLE the role of the teacher shifts to that of a facilitator of learning. "Constructivism adapts the instructor's role to include assisting learners in the construction of knowledge rather than reproduction of facts and data" (Phillips & Volker, 2014, p. 129).

Phillips and Volker (2014) discussed the characteristics that they identified as important parts of a CLEs. They argued that effective constructive learning environments should have projects or activities that are based on real life, to build on real-life problem-solving skills. The learning environment should also be an open, flexible, and a practical setting. The learners should be strongly involved in setting goals and assessment should be continuous and allow for numerous perspectives. Furthermore, the facilitator of the CLE must allow the students time for reflection and monitor and coach performance of students while encouraging effort, collaboration, and motivation from students (Phillips & Volker, 2014). Many types of CLE's exist, they can be classrooms, labs, or even real-life settings, but to be effective, the characteristics described should remain the same.

Comparing the descriptions and critical characteristics of CLE's, a SmartLab® appears to be a good example of a CLE. The design of the room is such that there is no real front or back of the classroom, making lecture (or teacher-centered teaching) nearly impossible; thus, open and flexible. The SmartLab® includes computers, curriculum (K-12), software, project kits, assessment templates, facilitator training, and technology support. Li, Yang, and MacLeod (2019) describe the constructivist smart classroom as a learning environment that is quickly emerging as an alternative classroom model that integrates active learning with advanced technology to improve learners' socialization and achievement.

As discussed, student ownership is important in a SmartLab®. The students, guided by the curriculum, form their own goals (with partners) and document their learning process

(reflection)in a journal throughout the entire learning engagement which is documented in an ePortfolio. The SmartLab® facilitators are trained in the lab environment where they must meet a specific set of competencies (see Appendix C) that describe the role of the facilitator which is aligned with the critical characteristics described by Phillips and Volker (2014) before they are approved to facilitate lab sessions. Facilitators are trained to allow students time for reflection and to monitor performance of students while encouraging effort, collaboration, and motivating their students. The facilitators role is to help students overcome obstacles, without providing direct instruction. Facilitators provide formative assessment and adjust and intervene with students when necessary to help provide them with connections and aid them in overcoming perceived limitations. Facilitators are not intended to be a content expert; they are instead considered the facilitator of learning. The idea of constructivist learning environments can be traced back to constructivist learning theories that developed in the mid 1900's.

Constructivist learning theories began with two prominent figures, Jean Piaget and Lev Vygotsky. Although each researcher differed in their opinions regarding how constructivism should be conducted in classrooms, their overall theories were similar in that they agreed that students will learn or are better able to understand a concept, if they themselves have a hand in constructing it. Constructivism focuses less on content and more on the learner (Gold, 2001). The focus is centered instead of on what the student is learning and more on the skills that they are acquiring while completing an activity.

Constructivism is a very broad term that can refer to or be interpreted several ways for example; hands-on or project-based, but most references can be placed into one of two broad categories of constructivism; cognitive constructivism or social constructivism. Described in

more detail in chapter 2 are the similarities and differences between Piaget's focus on cognitive constructivism vs. Vytgotsky's focus on social constructivism. Powell and Kalina (2009) explain the differences between cognitive and social constructivism:

> Both theories claim that guided forms of teaching or facilitation are necessary, as students construct their own concepts and understanding of what is being taught. Students need guidance when teachers explain complex topics and knowledge has to be brought out of them since they have their own experience to draw on. Piaget's theory has a heavy emphasis on the reasoning ability of individuals and how individuals interpret knowledge. Vygotsky believed that there were variables such as, social interaction, culture and language that affected how the individual learned knowledge. (Powell & Kalina, 2009, p.246)

Both cognitive and social constructivism can be observed in a SmartLab® learning environment, but due to the social nature of the lab, social constructivism seems to be a more accurate theory to represent the learning that occurs in the SmartLab®.

Social constructivism focuses on the social cognition model, which describes learning as a social, collaborative activity. Vygotsky (1978) believed that student learning took place within the zone of proximal development (ZPD). The ZPD is the potential area of learning for a student when supported by their teacher or peers in a collaborative environment. SmartLab® supports social constructivism as the environment is collaborative in nature and requires the focus and responsibility of learning on the learner who assimilates the knowledge into their existing understanding using guidance and communication with peers.

Ultimately, the SmartLab® environment consists of all of the effective characteristics in models of teaching, as were defined by Joyce et al. (2015). Furthermore, SmartLabs® are

designed as CLE's and use a constructivist methodology that is supported in research as being effective to support student learning. Teacher methods and training are focused on the teacher in the role of a facilitator described by Krahenbuhl (2016) as a constructivist pedagogy that consists of teaching methods that are focused on the active learning of the students. In the SmartLab the learners construct their own meaning of what they have learned, dependent on an existing understanding, social interaction in the classroom, and facilitator guidance while using authentic learning tasks. The student centered, project-based environment found in a SmartLab®, may contribute to student development of twenty-first century skills and thus investigating the impact it has on learning is important. SmartLab® environments require students to have ownership in their learning and as they work through their projects the focus of learning is not the specific curriculum but on the development of twenty-first century skills. Finally, participation in SmartLab® may expose students to potential career paths they may never had known existed.

Providing an opportunity for technology-based environments that focus on twenty-first century learning to be incorporated in rural schools is one step towards equity in the state of North Dakota. This opportunity may play a role to narrow the digital divide that exists and eliminate technology related obstacles for schools with limited staff and resources. Data related to the impact that SmartLabs® have on student learning and teacher methodology will be valuable to determine if a further investment is warranted.

Purpose of the Study

The state of North Dakota under the leadership of the current Governor, has placed great emphasis on education. The Governor has developed five strategic initiatives for the state that include main street development, behavioral health and addiction, transforming education,

tribal partnerships, and reinventing government. Focusing on the transforming education initiative, the Governor states that:

> With nearly all the world's information now available for free online, educators, parents, businesses, community organizations and legislators must all play a role in transforming the education system. It's not enough for students to do well on traditional measures. The challenge is how to equip them with the skills and mindsets they need to be creative problem solvers, effective communicators and informed, responsible citizens who are strong collaborators. (Office of Governor, State of North Dakota, 2016).

Furthermore, the governor has formed a task force charged with "providing direction on how state government can empower districts to adopt student-centric learning practices designed to support a twenty-first century economy impacted by rapid technological change." (Office of Governor, State of North Dakota, 2016).

The North Dakota Center for Distance Education (NDCDE), a state agency and online school in the state of North Dakota is moving forward to meet the need of students in the state by following the strategic initiative laid out by state leadership. NDCDE's mission is to ensure that all North Dakota middle and high school students, regardless of location, have access to educational opportunities that meet or exceed expectations for the quality of curriculum, ongoing contact time with highly qualified teachers, the selection and use of suitable educational technology, monitoring course delivery efficiency and effectiveness, and student learning (North Dakota Center for Distance Education, 2019). NDCDE has partnered with Creative Learning Systems (CLS), the developers of SmartLab®, to offer SmartLabs® in the state of North Dakota. A fully installed lab from CLS would cost on a range from $180,000 to

$200,000. With the partnership, NDCDE has taken on the role of installation, facilitator training, and technology support, and has negotiated a reduced cost (about 1/3) for all North Dakota schools to make the SmartLab® environment a realistic option for a school regardless of population, funding, or location.

Local leaders including the Governor's education representatives, the state superintendent, the CIO of the Information Technology Department in North Dakota, as well as several state legislators and senators have toured and experienced SmartLabs® in North Dakota and are interested in supporting statewide implementation, however data on the impact of a SmartLab® implementation in North Dakota would be of great benefit.

There are hundreds of SmartLabs® currently operating around the country. A case study done in 2002 at The Southwest Secondary Learning Center in Albuquerque, New Mexico provided a snapshot of the effect a SmartLab® had on their students' standardized test scores (Creative Learning Systems, 2002). The Southwest Secondary Learning Center installed and began a SmartLab® program in 2002, and using the Terra Nova standardized test scores for 7th grade students and following the same cohort over the next two years showed a 52% core subject area test score increase that the school attributes to the incorporation of the SmartLab® program at their school (Creative Learning Systems, 2002). This case study has shown that there have been gains in student learning, but there is a need for a more concrete study regarding the impact that SmartLabs® have on students and teachers, especially in rural schools. My hope is that this study in some small measure, can provide the impetus for more research on this important topic. There has only been one white paper published regarding the SmartLab® design and ability to support instruction, at it provides only a summary of "the evidence related to effective instructional practices that are particularly relevant to the Creative

Learning Systems SmartLab system and to show how the SmartLab model and curriculum align with these findings" (IESD, 2011,p.1). A gap exists in the empirical research regarding SmartLab® impact on student learning, and teacher and student perspectives. This study will aim to provide data to show the impact that a SmartLab® implementation has had on four rural schools in North Dakota.

Research Questions

The overall research question for this study can be described in multiple parts;

What is the impact of a SmartLab® implementation on students and teachers in a rural school?

- Impact is measured in terms of
    - student learning (twenty-first century skills)
    - student and teacher perspectives on how their learning and teaching has changed.

The research goal in this study is to assess the impact on student learning in terms of twenty-first century skills, and to gain an overall understanding of student and teacher perspectives regarding the impact of the installation and use of a SmartLab® at four rural schools in North Dakota.

Research Paradigm

This study is guided by social constructivist paradigms and perspectives, and the use and development of twenty-first century skills as a measure of student success. This study was a mixed-methods phenomenological study; QUAN→qual. Because this study focused on the impact of SmartLabs® on rural schools in North Dakota, it was important to include not only the impact on student learning, but also the impact or impressions on students and teachers. Specifically, how has this lab changed them, if at all? This could be in terms of their learning,

the way they look at learning, or for teachers, their teaching methodology.

Potential Significance and Ethical Concern

The results of this study could be very significant for the state of North Dakota and could influence decisions as to statewide implementation of a the SmartLab® program. The results of this study have the potential to impact students, teachers, schools, districts, and potentially the whole state. Furthermore, this study has the possibility to contribute to the literature regarding the constructivist teaching methodology and to support the teaching of twenty-first century skills to prepare students. Ethically speaking, the conduction of this research with human participants will result in no harm to any participants. The possibility does exist that the administration of an exam may cause a small amount of student anxiety but should be alleviated by the student reading the assent and consent forms and with the interaction and discussion with the researcher.

Assumptions

Some of the assumptions that were made in this study were that the facilitators and teachers utilized the SmartLab® the way that they were trained. This assumption included use of the student assessments templates. Other assumptions included that the rural communities that were a part of this study were representative of rural communities in North Dakota.

Delimitations

Delimitations are restrictions that will be imposed prior to the beginning of the study. Some of the delimitations for this study are:

1. The study is delimited to only four rural schools in the state of North Dakota based on their installation of a SmartLab® in the Summer of 2018.

2. The populations of the schools are very small and not all the students in the school were utilizing the SmartLab® right away. Thus, grade levels were selected based on SmartLab® use.

Summary

Technology has changed the face of teaching and learning. Rural schools may be at somewhat of a disadvantage due to funding, teacher candidates and geographical location. It is however critical to prepare students for careers that may not yet even exist. There should be equity in opportunities and access to technology for all students regardless of where they live. The SmartLab® is a CLE that incorporates nearly all the identified effective teaching models identified by Joyce et al. (2015). SmartLabs® are a turn-key option for schools in the state to integrate technology to support the development of twenty-first century skills. The SmartLab® option has the potential to level the playing field between urban and rural schools and their ability to offer twenty-first century learning opportunities. Research is necessary to determine the impact of the SmartLab® initiative in rural schools in the state prior to the potential statewide implementation of SmartLabs® in all schools.

CHAPTER 2. REVIEW OF LITERATURE

Introduction

Technology integration in rural schools can be a great challenge. Although providing students with opportunity and choice is important to schools, many hurdles exist that can restrict their abilities to do so. For example, in rural areas, there is often a challenge to recruit and retain quality teachers. Kristiansen (2014) identified standards that can be used to recruit effective teachers but reports that "…schools in deprived inner cities and rural areas, have trouble recruiting and retaining such ideal teachers" (p.630). To recruit teachers to rural areas, and to pay them competitively is not often feasible for small rural schools. Malhoit (2005) found that is often can be more expensive (due to geography, poverty, and at-risk youth) to run a smaller rural school than a larger one.

Although the reasons for a failure to attract and competitively pay teachers is outside the scope of this study, the consequences are that, rural schools that are often limited in offering opportunities and options for rural students. There is currently a critical teacher shortage in all areas the state of North Dakota (North Dakota Education Standards and Practices Board, 2018). School districts are unable to attract qualified teachers to their districts and when they do manage to hire a qualified teacher, the attrition rate is extensive.

Rural areas also face the challenge of offering and utilizing the most up to date technology to their students. A digital divide exists regarding access to hardware, connectivity, digital literacy skills, the availability of technical support and access to technologically skilled teachers (Resta & Laferriere, 2015). "Policy makers in rural areas are often split between wanting to support the notion of more 'school choice', but not knowing how to provide choices to their constituents in small or sparsely populated areas" (AASA, The School Superintendents

association, 2017, p.4). The state of North Dakota has been working to address this issue, but today the divide exists. Another challenge all schools are facing today is preparing student for the challenges of the twenty-first century.

Careers, jobs, technology, and challenges that do not currently exist, or have yet to be imagined are what educators are expected to prepare students for in the twenty-first century. Husin et al. (2016) argued that there was a need for students to be equipped with twenty-first century skills to be competitive in this era, especially considering science and technology and their advancement. This is further supported by Germaine, et.al (2016) who also claim that twenty-first century skills are essential to student success in today's world. There are many definitions of twenty-first century skills, or twenty-first century learning, but a common theme regardless of the definition is, preparing students to learn how to approach learning successfully. Furthermore, the development and preparedness of teachers and awareness and use of effective teaching models must also occur to meet twenty-first century student needs. Content remains important as it provides a base knowledge for understanding but preparing students with skills that will provide them what they need to be successful in an ever-changing world is critical to compete in the world today. Finally, providing the right type of environment for students to thrive and succeed is a critical component to supporting successful learning. Environments which motivate students to explore, reflect opinions, and develop their own interpretations to solve problems collaboratively is where effective learning happens (Vygotsky, 1978). The author contends that the incorporation of SmartLabs® might address many of the challenges facing rural school districts that were mentioned previously.

The Concept of SmartLabs®

SmartLabs® were developed by Creative Learning Systems, a Colorado based education company. The SmartLab® design is like other CLE designs as it includes a project-based, hands-on, student-centered environment. SmartLabs® include computers, software, project kits, performance-based curriculum (including alternative and renewable energy, circuitry, computer graphics, digital communications, mechanics and structures, robotics and control technology, scientific data and analysis, and software engineering), assessment templates, technology support and training for teachers in constructivist environments.

In 2011, a white paper that included a summary of independent research that was conducted by IESD (2011) regarding SmartLabs® concluded in its key findings that:

1. Multidisciplinary STEM instruction (combining science, technology, engineering/design, and math) following the basic model used by SmartLab® has the potential to improve student learning and academic achievement for a broad spectrum of learners.
2. Characteristics of the SmartLab® model are endorsed by educational researchers as supporting improved student learning and academic achievement.
3. Characteristics of the SmartLab® model have been shown to improve students' motivation to learn and/or engagement (IESD, 2011).

These conclusions provide support that participation in the SmartLab® may play a role in the improvement of student learning, academic achievement and motivation and/or engagement. The focus in this analysis was surrounding math and science scores, and not the acquisition of twenty-first century skills. The current study will aim to dig deeper into the overall impact on the SmartLab®, including the effect on twenty-first century skills, student and teacher

perspectives, as well as the impact on teacher methodology.

The SmartLab® environment is designed for students to work with a partner while they observe other students working around the room. The SmartLab® is organized as islands that have three peninsulas protruding. Each peninsula has one computer and two chairs. The islands are strategically placed around the room and the peninsulas face each other so students can view what other groups are doing but are not distracted and are able to focus on their project (Figure 1). Furthermore, there are group activity centers for collaboration and larger-scale building projects. The design of the room is supportive of active participation and allows for social interaction.

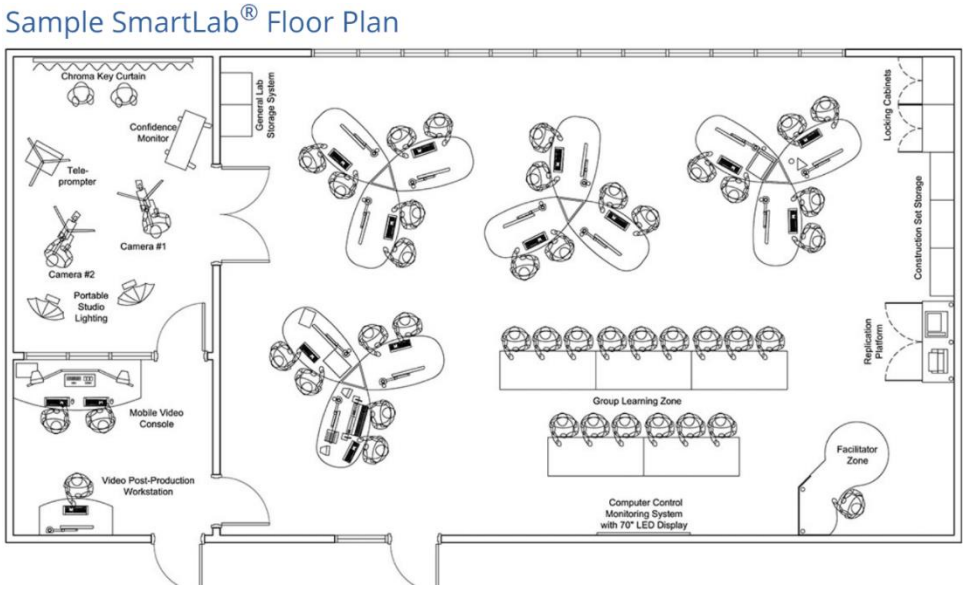

Figure 1. Example of a SmartLab® Floorplan. (Creative Learning Systems, 2018).

SmartLab® has similarities to a design described by Li, et al. (2019) called "the smart classroom". The smart classroom has seven critical features. They describe this classroom as a "face-to-face classroom that employs active learning process in combination with advanced forms of technology" (Li, et al.,2019, p. 350). The features they identified included connectedness, inquiry learning, student negotiation, reflective thinking, functional design,

multiple sources, usefulness, and ease of use. Li, et al. (2019) focused-on connectedness as one of the critical parts of the smart classroom and discovered that a preference for connectedness was positively associated with all the critical smart classroom features.

Connectedness defined by Rovai (2002), is a deeper than just interpersonal interaction, there should be a sense of belonging, and students should have active participation or engagement in the social activity to achieve this feeling of connectedness. This concept of connectedness is supported in the SmartLab® design as students are provided a learning engagement and they construct goals with partners and ultimately share with the class what they have done in a presentation format.

Curriculum. The SmartLab® design incorporates project-based curriculum with kits, software and hardware. A themed organization of the lab incorporates rocket ships. Each of the computers has a rocket icon on the computer desktop that is deemed the "launchpad". Each activity in the curriculum provided is referred to as a "learning launcher". Curriculum is designed and organized by a team of qualified curriculum developers and is available for grades K-12. Each learning engagement (launcher) has been aligned by a third party to both national as well as to each state's standards to provide facilitators the opportunity to align activities to their specific needs. The curriculum is organized into categories (Figure 2) that include activity cards geared toward K-2 students, as well as (continuing with the theme of rockets) lift-off challenges and express challenges that incorporate elementary level activities and whole classroom activities respectively. In total there are over 300 learning engagements available as part of the curriculum that is included with a SmartLab® installation. Furthermore, because the curriculum is cloud based, CLS is consistently adding to the curriculum breadth.

Figure 2. SmartLab® learning engagement categories (Creative Learning Systems, 2018).

Each learning launcher category is then further divided into specific topics within that category (Figure 3). Each topic incorporates a piece of software, or a kit that the students will use to meet the requirements of the activity. Each topic is further divided within into levels for developing deeper understanding as the student progresses through the activity (Figure 4).

Figure 3. Topics within each learning engagement category. (Creative Learning Systems, 2018).

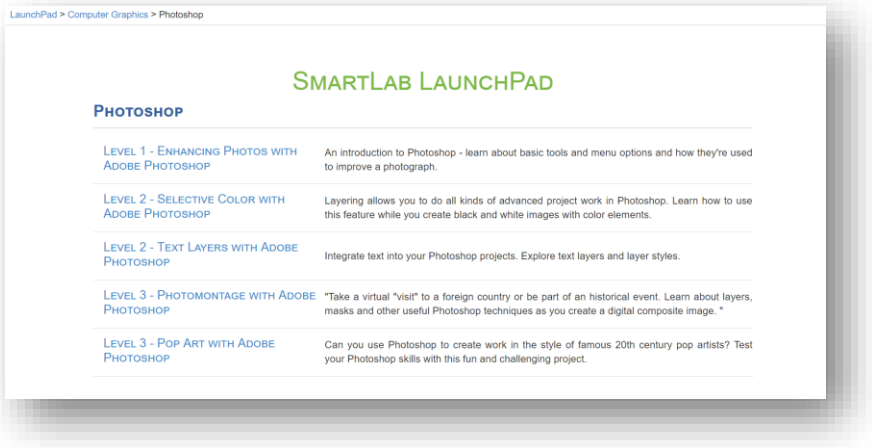

Figure 4. Leveled activities within each topic. (Creative Learning Systems, 2018).

Each learning launcher contains multiple sections (tabs) that include a challenge, what you should know, do it, and extend yourself sections (Figure 5). The "challenge" identifies what the student is to do in the activity. The "what you should know" section provides background, terminology, links to videos, and other important information to provide the learner with some background into the topic. The "do it" section gets them started and they can begin the activity as soon as they reach this point. Finally, the "extend yourself" section allows students that would like to go further in a topic to continue learning by providing more ideas and or options to learn more about the topic. This provides the students with everything that is needed to guide themselves through the learning engagement.

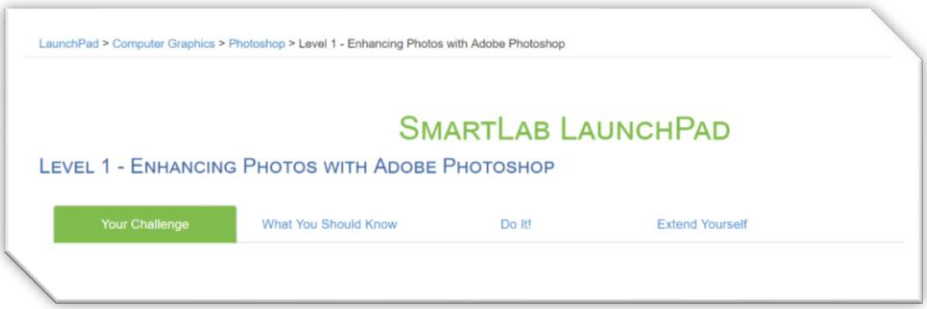

Figure 5. Organization of each launcher (Creative Learning Systems, 2018).

Assessment. The SmartLab® utilizes portfolio-based assessment. Each student is required to journal about their experiences, given a template, and to document, present and conduct a self-assessment. Students are required to collaborate, communicate their thoughts and reflect on their learning daily and with their partners.

Creative Learning Systems (2018) described the projects and process below:

> Project engagements are not rigidly structured activities but are motivated by genuine learner inquiry and a problem-based perspective…all projects follow a similar process:

- Students create SMART (specific, measurable, attainable, relevant, time-based) project objectives in collaboration with their facilitator
- Projects are designed and developed to meet the objective
- Projects are multidisciplinary and utilize applied technologies
- Problem-solving is emphasized and failure celebrated as an opportunity to learn
- Process skills such as collaboration and time-management are emphasized and assessed
- Students document their process, learning and achievements in their ePortfolio

Supported by a facilitator, and working with a partner, students will identify a SMART goal, and using pictures, and videos to capture images of their projects. Students will create a portfolio of their learning that incorporates reflection, and their thought processes, as well as challenges and successes that they have encountered during the learning. This reflection incorporates not only the student's interaction with the content, but with their communication, time management, and collaboration. Joyce et al. (2015) discussed effective models of teaching and the important characteristics that need to be incorporated. Each of the characteristics is referenced in the projects and processes described in the SmartLab.

NDCDE. The North Dakota Center for Distance Education (NDCDE), is a state agency that works with all schools in the state of North Dakota, but particularly with rural schools to offer educational opportunities across the state. The relationship that NDCDE has with schools, more specifically rural schools, has provided insight into the needs that exist in the schools in the state. One such need was the desire for rural students to have accessibility to the same types of opportunities as the more urban schools, especially in terms of access to technology. Often limited resources due to location, teacher availability, and funding restrict the opportunities that schools can offer. Resta and Laferriere (2015) refer to this phenomenon as

the “digital divide”. The divide exists when there is limited access to and usage of information and communication technology (Resta & Laferriere, 2015). Furthermore, they describe how schools often support technology enhanced learning but underestimate the difficulty of implementing the technology, in the case of rural schools this could be due to funding, location and teacher availability. NDCDE, as a state agency, is required to support state initiatives as per the agency’s mission. Current leadership in the state has formed a task force charged with “providing direction on how state government can empower districts to adopt student-centric learning practices designed to support a twenty-first century economy impacted by rapid technological change.” (Office of Governor, State of North Dakota, 2016). Additionally, the Governor of North Dakota has put into action during his term, the “pillars of economic success” (Office of Governor, State of North Dakota, 2016), which are part of his five strategic initiatives for the state of North Dakota. He is quoted as saying:

> To create a 21st century economy, we need to build on three pillars of economic success: a skilled workforce; smart, efficient infrastructure; and healthy, vibrant communities. By reinventing education, we will create a skilled workforce that matches the high-paying jobs of today and tomorrow. Utilizing our current infrastructure to its fullest potential, we can reduce the cost of local government and create vibrant, healthy cities. (Office of Governor, State of North Dakota, 2016)

The five strategic initiatives that are the focus of this plan are: main street development, behavioral health and addiction, transforming education, tribal partnerships, and reinventing government. Focusing on the transforming education initiative, Gomez (2017) reported that the “first challenge is to ensure that we’re providing a twenty-first century education to our citizens from Pre-K to the moment they earn their college diploma and beyond. With an

increased emphasis on STEAM – Science, Technology, Engineering, Arts and Math". It is critical that all areas of the state are able to "transform education" regardless of their location.

To support the strategic initiatives, NDCDE partnered with Creative Learning Systems (CLS) to provide the SmartLab® option to rural schools. SmartLabs® allow smaller schools the chance to offer a high-tech CLE in their own school using resources and staff that they have. If the funding or cost of purchasing a SmartLab® is an issue for the school, NDCDE has secured a financing option through a company that provides financing to educational institutions nationwide. NDCDE has also negotiated with CLS to take over the installation, training and support for all labs in North Dakota to further reduce the cost of the SmartLab® purchase for rural schools through CLS.

Limited resources. Although the funding formula in the state of North Dakota attempts to provide equality, equity is often not achieved. In fact, Malhoit (2005) reported that considering geographic location, at-risk youth, and poverty, it is often more expensive to fund a rural school even with a lower population than it is to fund larger schools. This data is important to consider as the state of North Dakota is largely rural, according to the North Dakota Department of Commerce (2018), North Dakota has 53 counties, 39 of those counties are classified as completely rural.

Large school districts often have the means to provide technology resources, equipment, and training whereas small schools can often struggle with offering similar opportunities. Payments to schools come from the general funds that are based on per-pupil funding, thus the fewer students enrolled in the school, the smaller the payment. The formula is more complicated than only a simple student count, but the bottom line is that inequities exist. There are 175 school districts in North Dakota and 482 schools (ITD, n.d.). Schools in the

state of North Dakota have student populations that range from as small as a rural K-12 school with only 23 students, to a more urban high schools with nearly 1500 students for only grades 9-12. In total in the 2018-2019 school year there were 113,646 students enrolled in school in the state of North Dakota (ITD, n.d.). Discounting enrollment of the five largest school districts from the largest cities in the state which include Fargo, West Fargo, Grand Forks, Bismarck and Minot, there are 62,891 students remaining or 55% of all student enrollments in the state of North Dakota that are considered as rural. It is important to provide the same options and opportunities to all students regardless of location, rurality, and funding.

The SmartLab® is seemingly supportive of the Governor's strategic plans discussed earlier, and that are currently in place in North Dakota. There is a possibility that SmartLabs® could become a statewide initiative and all districts could be provided the opportunity to incorporate a SmartLab® program into their school. This could potentially bring twenty-first century experiences of a CLE to all students, specifically the over 55% of students that are in rural schools in North Dakota that would otherwise potentially struggle to gain access to this type of environment. The rural state of North Dakota has the future of the students in mind, the question is; can schools across the state prepare students, especially rural students, for the twenty-first century if nothing changes?

This study will investigate the impact of a SmartLab® on rural schools in the state of North Dakota. This determination will provide perspective on the value of SmartLabs® as an investment for the state.

Characteristics of a Quality SmartLab® Implementation

As discussed previously, a SmartLab® is a turn-key environment that includes everything that is needed to implement the program from the day of install with no additional design or purchase of materials necessary. An implementation of a SmartLab® consists of eight steps:

1. Prepare the room with appropriate electrical and network capabilities.
2. Prepare the computer image and software packages including licensing codes.
3. Unpack, install, and organize the lab materials.
4. Image computers set up lab
5. Enroll and provide feedback to future facilitators in online training.
6. Conduct face-to-face training, including student interaction as part of the requirement.
7. Trainer will return to SmartLab® to observe and provide assistance and feedback to facilitators.
8. Maintain connections with school facilitators and provide collaborative opportunities for statewide facilitators.

All components of SmartLab® installation are important, but initial facilitator training is key. The role of the facilitator, and the buy-in of the methodology is vital to a successful lab implementation. Training and support provide teachers with the chance to practice the facilitator methodology and reflect on the results. Gentry et.al, (2014) stated that if teachers were more comfortable with technology their students would become better twenty-first century learners. NDCDE plays a key role in preparing teachers or other trained individuals to be facilitators in the SmartLab® environment. The facilitators enroll in an online course and then participate in a two-day intensive face to face session where they work with students in

the SmartLab® environment. Facilitator competencies must be achieved and demonstrated to receive facilitator certification from NDCDE (See Appendix C).

There do appear to be ideal characteristics to be desired in facilitators. Aydogdu and Selanik-Ay (2016) found that teachers that had graduate degrees were more open to using constructivist methodology in teaching. Although not all-inclusive the list included comfort with ambiguity, ability to problem solve, willingness to learn new things including software, and using technology, similar to that of the skills students are learning in the SmartLab®. Finally, Barak (2017) shared what were identified as attributes for teaching and learning in the twenty-first century that included: adapting, collaborating and communicating, generating data and managing information, and encouraging exploration (Barak, 2017). The selection of individuals with these characteristics is recommended to schools when choosing a facilitator, with the understanding that support, professional development, and training will be provided to help each facilitator to be as successful as possible.

Review of Empirical Evidence

Twenty-first century skills have been defined in many ways. Husin et al. (2016) believed that the criteria needed to produce a generation of individuals capable of handling challenges in the twenty-first century were digital age literacy, inventive thinking, effective communication, and high productivity. Common categories of twenty-first century skills have been identified and seem to repeat throughout most literature. There have been several studies that have attempted to identify and categorize these skills (Aslan, 2015; Claro et al., 2012; Ercikan & Oliveri, 2016; Geisinger, 2016; Germaine, et.al, 2016; Husin et al., 2016) and some have gone further and identified specific subskills that can be considered or measured for assessment (Germaine, et.al ,2016; Husin et al., 2016).

Aslan (2015) stated that the following important competencies are key twenty-first century skills. They included creativity, independence, self-confidence, self-efficacy, teamwork, communication, complex thinking, empathy, knowledge on searching and managing, research methodology, presentation and discussion skills, digital skills, punctuality, reliability and patience. Others have suggested additional organizational components such as the two specific categorical approaches discussed by Geisinger (2016); included are the Organization for Economic Cooperation and Development (OECD) approach and the Partnership for Twenty-First Century Learning Approach (PTCLA). The OECD included categories were cognitive (i.e. non-routine problem solving), intrapersonal (i.e. self-management, time management, self-development, self-regulation, adaptability, executive functioning), interpersonal (i.e. complex communication, social skills like collaboration, teamwork, cultural sensitivity, and dealing with diversity) and technology skills (i.e. research and information fluency, entrepreneurial skills, and financial literacy). PTCLA had four categories including learning and innovation skills (i.e. creativity, critical thinking, problem solving, communication, and collaboration), information, media and technology skills (i.e. informational literacy, media, information, communication and technology literacy), and life and career skills (i.e. intrapersonal skills, flexibility, adaptability, initiative, productivity, accountability, leadership, responsibility, and self-direction) (Geisinger, 2016).

Ultimately, all the categories and subcategories fall within the 4 C's framework put forward by the National Education Association (NEA) (as cited in Germaine, et.al, 2016). The main categories included were critical thinking, communication, collaboration, and creativity; and all subskills were included within the main skill. The most commonly accepted standards for twenty-first century competencies are those defined by the International Society for

Technology in Education (ISTE) and have been what has become internationally recognized as the definition of twenty-first century skills. These skills include, digital citizenship, knowledge construction, innovative designer, computational thinker, creative communicator, global collaborator, and empowered learner. Competencies for each of these skills have been identified and as a result, instruments of measurement of twenty-first century skills have been generated such as the Digital Literacy Assessment (DLA) created by content experts at Learning.com (2018) (Appendix D).

Twenty-first century skills are not necessarily new skills but are simply defined as such to indicate that they are necessary for student success in today's world. These skills can be very complex to categorize and measure, "…unlike measuring simpler constructs such as factual knowledge or isolated skills. There are many additional challenges in assessing complex constructs" (Ercikan & Oliveri, 2016, p. 310). Ultimately the phrase twenty-first century skills have been an "overarching description of the knowledge, skills, and dispositions seen as prerequisites for success in the global workplace of the future" (Germaine, et.al, 2016, p.19). Educators need to provide opportunities, practice conducive methodologies, and provide suitable environments that support this type of learning process. Can SmartLabs® do all or some of this?

Implementation of SmartLabs® as a Pedagogical Technique in Secondary Schools

The SmartLab® learning process is supported in brain science literature as described by Sesmiarni (2015). The five needs for the brain for learning to occur described by Sesmiarni (2015) include emotional needs (comfort), social learning, cognitive learning system (no lecture, instead a facilitator), physical manipulation or interaction, and reflective learning. The author contends that through the utilization of SmartLabs®, many of the requisites mentioned

in the above section can be realized. In a SmartLab® environment, each of the needs described are met. First, emotional needs require a level of comfort in learning. The SmartLab® is an environment where failure is not a bad thing. Students work with their partners and fail or succeed they work together with support from the facilitator to solve problems. Next, social learning is at the center of every learning activity. Students work with partners supported by the social cognition model, which describes learning as a social, collaborative activity as part of a constructivist environment (Vygotsky, 1978). Instruction using a facilitation is next on the list described as the cognitive learning system. SmartLab® facilitators are trained to support student learning using guidance, no lecture. The facilitators role in a SmartLab is to help students find answers and solve problems by empowering them to seek out answers. As Gold (2001) explained, constructivism focuses less on the content and more on the learner. Next, physical manipulation is a concept that has been supported over and over in effective teaching models (Brandon & All, 2010; Joyce et al.,2015; Vytgotsky,1978). In the constructivist framework regardless of the type of constructivism practiced (social or cognitive) students will learn or are better able to understand a concept, if they themselves have a hand in constructing it. Finally, reflective learning is part of the assessment for SmartLabs®. Students are required to journal and reflect on their learning process. This opportunity for reflection is a critical part of the learning process. Reflection is referenced in Joyce et al. (2015) in terms of formative assessment, Philip and Volker (2014) discuss the need for assessment in CLE's to be continuous and allow for multiple perspectives, and because reflection can be akin to critical thinking, it is important to consider that the twenty-first century skills that are necessary for students to build to be successful, will be supported by their ability to reflect on their own learning processes.

Facilitators. Facilitators that work in the SmartLab® do not necessarily have to be experts in all areas of technology, they must however be malleable, flexible, and willing to learn. Barak (2017) identified "four attributes for teaching and learning in the twenty-first century: (a) adapting to frequent changes and uncertain situations, (b) collaborating and communicating in decentralized environments, (c) generating data and managing information, and (d) releasing control by encouraging exploration" (p. 283). These attributes define the characteristics of an effective SmartLab® facilitator very well. Individual characteristics aside, there are important elements in teaching methodology that are critical for learning to occur.

Through researching human behavior and the human brain Caine et. al. (2009) identified what they described as the three critical elements of great teaching for optimal learning to occur. These critical elements include relaxed alertness, orchestrated immersion in complex experience (OICE), and active processing of experiences. They proposed that not only are students responsible for their own learning, but there are things that teachers can do (methodology and environment) to support their success. Each of these elements can be articulated as occurring in a SmartLab® environment.

Facilitators in a SmartLab® practice relaxed alertness by supporting students and engaging them in safe, yet challenging experiences. Failure is not considered a bad thing, but it is seen and explained as a learning opportunity. An OICE as defined by Caine et. al. (2009) as the offering of rich experiences that fully engage student thinking. These experiences allow the students to take ownership of their learning and truly immerse themselves in the experience. Facilitators support OICE's in the SmartLab® as they guide learning as it is critical for students to own and immerse themselves in the process or project. Finally, the active processing of the learning activity can be described in a SmartLab® in the type of assessment

that is done. As students work through their projects with their partners, they are reflecting, documenting and making connections while facilitators observe, and guide. Through conversations facilitators formatively assess student understanding and redirect students in need of guidance. Furthermore, much like the smart classroom described by Li, et al. (2019), students can gain a sense of connectedness as they have these conversations and work through problems with partners. New SmartLab® facilitator training consists of online training (to acclimate the individuals to the SmartLab® methodology and curriculum) followed by a two-day face to face immersive experience working with students and working through the projects. The new facilitators are provided training in the SmartLab® using the constructivist methodology and are required to meet the expectations/competencies (Appendix C.) mandated to gain SmartLab® facilitator certification.

Theoretical Background of the Constructivist Approach to the Study

This section is intended to provide the reader with a basic background as to the use and application of the constructivism learning theory to this study. The two most prominent figures in the areas of constructivist learning theories are Jean Piaget and Lev Vygotsky. Each had a very similar idea of the most effective approach to learning but differed in their application. Based on the work of these two pioneers, the theoretical concepts of constructivism or constructivist learning theory can be broken down into two different types; cognitive constructivism and social constructivism.

Overall “Constructivism is a theory founded on observation and scientific study about how people learn” (Brandon & All, 2010, p. 90). The focus in a constructivist classroom is the movement from a teacher centric to a student-centered environment. Koohang, Riley, Smith, and Schreurs (2009) developed a model based on the constructivist learning theory that

required three elements to be included; “design of activities, learning assessment, and instructor’s roles regarding learning activities” (p.94). Koohang, et.al, (2009) further describe a constructivist model as:

> … learning activities that included collaboration, cooperation, multiple perspectives, real-world examples, scaffolding, self-reflection, multiple representations of ideas, and social negotiation. The learning assessment elements consisted of instructor assessment, collaborative assessment, and self-assessment. The instructor’s roles were coaching, guiding, mentoring, acknowledging, providing feedback, and assessing student learning (p.94).

Powell and Kalina (2009) summarize both Piaget’s cognitive constructivism and Vygotsky’s social constructivism very completely describing the focus of each and providing a comparison. Generally, Piaget’s cognitive constructionism theory focuses on the leaner in a certain cognitive stage of development where a teacher could identify what the student is developmentally ready to learn. Furthermore, Piaget claimed that as students learn, new knowledge is incorporated into existing understanding referred to as constructs. If new material does not fit into an existing understanding, the construct is then modified. In providing a description of Piaget and cognitive constructivism, Powell and Kalina (2009) stated that:

> Piaget's main focus of constructivism has to do with the individual and how the individual constructs knowledge. Cognitive constructivism came directly from Piaget's work. Piaget's theory of cognitive development proposes that humans cannot be given information, which they immediately understand and use; instead, humans must construct their own knowledge (Piaget,1953) (p. 242).

Although similar, Vygotsky incorporated a social component to constructivism and requires the contribution of a teacher and fellow students as active participants in the student's learning path. Powell and Kalina (2009) described Vygotsky's social constructivism as:

> Social constructivism is a highly effective method of teaching that all students can benefit from, since collaboration and social interaction are incorporated. This type of constructivism was formed after Piaget had already described his theories involving individual or cognitive constructivism. Lev Vygotsky, the founding father of social constructivism believed in social interaction and that it was an integral part of learning. Social constructivism is based on the social interactions a student in the classroom along with a personal critical thinking process (p. 243).

A SmartLab® is a highly social, collaborative environment. Thus, the theory of Social Constructivism is related and fully supported in the SmartLab® environment. The incorporation of both the social interaction with other leaners as well as that of the facilitator (teacher) is very important both in the SmartLab® as well as in the social constructivism theory of learning. Vygotsky's social constructive theory of learning requires invested teachers as active participants. This description is further supported in terms of SmartLab® as previously discussed as the facilitator plays a critical role in the success of students in the SmartLab®. In terms of this study, this the social constructivist learning theory is fully supported by North Dakota state leadership and described by leadership as beneficial, an example including the governor's strategic plan to "…empower districts to adopt student-centric learning practices designed to support a twenty-first century economy impacted by rapid technological change." (Office of Governor, State of North Dakota, 2016).

Constructivist Learning Environments.

As discussed previously, the role of the teacher or facilitator and the environment in which the learning occurs in constructivism is critical. The perceptions of teachers or facilitators in a constructivist environment is thus very important. Anagun (2018) conducted a study using an instrument to assess the perceptions of teachers regarding the impact of the constructivist design of their learning environments. Anagun (2018) ultimately determined that although no direct cause and effect relationships could be confirmed regarding teacher perceptions of their twenty-first century proficiencies and their abilities to manage a CLE, there were positive associations related to "holding more positive perceptions and all dimensions of a constructivist learning environment" (Anagun, 2018, p. 835). Furthermore, Anugun (2018) explained that teachers that have positive perceptions regarding their proficiency make positive arrangements in their classrooms to aid in the development of twenty-first century skills in their students. Although the CLE is student centered the teacher/facilitator role is critical to the success of the student as has been reiterated in this chapter. The facilitator of the CLE must allow the students time for reflection and monitor and coach performance of students while encouraging effort, collaboration, and motivation from students (Phillips & Volker, 2014). Self-efficacy and perceived ability in teaching or facilitating in a CLE can also be an important part of success in teaching in a CLE. Gentry et.al, (2014) set forth to discover how the self-efficacy of teachers using technology influenced their ability to support students in a CLE. Gentry et.al (2014) developed an instrument that could be used to identify teacher self-efficacy on using technology and incorporating it into their classroom, and ultimately posited that if teachers were more comfortable with technology their students would become better twenty-first century learners. To further emphasize and articulate the role of a facilitator in a

SmartLab®, it is important to reiterate that facilitators are not the bearer of content knowledge in a SmartLab®. Facilitators are not the authority of learning nor are they a lecturer, their role is as a facilitator of learning.

Khan (2013) describes the facilitator as a guide, a "teacher that has to support the learners to become effective thinkers" (p.64). A facilitator is a key part of the CLE. As mentioned previously, Phillips and Volker (2014) discussed the characteristics that they identified as important parts of a CLEs. Included they argue that effective constructive learning environments should have projects or activities that are based on real life, and that activities should build on real-life using problem-solving skills. Furthermore, they emphasize that the CLE learning environment should be an open, flexible, and practical setting. The learners should be strongly involved in setting goals and assessment should be continuous and allow for numerous perspectives. Finally, the facilitator of the CLE must allow the students time for reflection and monitor and coach performance of students while encouraging effort, collaboration, and motivation from students (Phillips & Volker, 2014). SmartLabs® meet all the characteristics identified by Phillips and Volker (2014) as to define a CLE and key to this section is the role of the facilitator as a guide. The facilitator in a SmartLab® supports students in learning by providing guidance, coaching and encouraging reflection.

It is important to acknowledge that much like any profession; the best and most effective facilitators are those that practice as a facilitator. Experience, time and willingness to learn will cultivate the best facilitators. In fact, Aydogdu and Selanik-Ay (2016) found that teachers that have graduate degrees were more open to using constructivist methodology in teaching. This could be due to their ability to persevere in continuing education as well as their experience in the teaching profession. Finally, as mentioned, Aydogdu and Selanik-Ay (2016)

describe successful facilitator characteristics in a CLE include (however not all inclusive) comfort with ambiguity, ability to problem solve, willingness to learn new things, and comfort using technology.

Criticism to constructivism. One of the more prominent arguments to the contrary of constructivism stems from one of the most fundamental components of the theory. Considering cognitive constructivism, learners are building on previously understood or learned material and incorporating or building on top to assume a greater understanding. What if the leaner has absolutely no previous understanding or if the concept is too abstract? Critics argue that there are no experiences from which to draw knowledge and therefore misconceptions or misunderstandings can result. Krahenbul (2016), emphasizes that educators in the twenty-first century are misguided into utilizing constructivism as a dominant pedagogy in their classroom based on misunderstanding between the learning theory of constructivism and the pedagogical theory of constructivism. He continues that although it sounds appealing in that students are left to construct their own understanding, and are treated as though they are experts, there are three fundamental flaws.

The first two flaws directly relating to the differences between experts and novices and the third is based on cognitive science and the memory system. Krahenbul (2016) argues that students cannot behave like experts to successfully learn in a problem or project-based environment because they have not invested expert time. Students who hold misconceptions to long periods of time tend to keep them. He continued that guided instruction has been more successful in regard to student learning and that unguided, discovery, and constructivist-based classrooms result in challenges to learning.

Although, Krahenbul (2016) does provide valid arguments and concerns, missing is the critical role of an effective facilitator to provide guidance and support to students in the constructivist learning environment. It is important to understand that although content in the constructivist classroom is essential, the skills that students are building in a constructivist learning environment are outside of specific content. Twenty-first century skills are the framework that will be used to incorporate specific content as the student advances as a learner. For example, the student may not be a robotics engineer after completing a robotics unit, but through guidance and social learning, the student, when encountering a similar challenge in the future, will have background and problem-solving skills to meet the challenge.

Research on the Relationship Between SmartLabs® and Learning Models

Joyce et al. (2015) have identified eight characteristics in teaching models that have been found to be most effective; they include,(a) helping students learn how to learn, a (b)constructivist orientation, (c)providing scaffolding for the learning process, (d)formative assessments, (e) twenty-first century skills, (f) cultural literacy and global awareness, (g) collaborative and cooperative skills and (h) creativity and convergent thinking. Defining teaching in today's world can be a challenge as there are barriers to preparing teachers with the "knowledge, skills, and systems of support to be successful in student-centered, competency-based, and diverse learning environments" (Casey & Worthen, 2019, p. 1). A challenge is presented when the goal is "Transforming K-12 education systems to meet new economic, civic, and cultural demands of our global society…" (Casey & Worthen, 2019, p.1). How can teachers meet the needs of the students if the teachers are not prepared or provided the tools to develop more complex teaching skillsets

Many studies have attempted to determine how best to deliver or provide an

environment best suited for students gaining twenty-first century skills. Gentry et.al (2014), thought that teacher efficacy may play a role. They discovered that teachers that were more comfortable with technology and in their ability to use technology were more apt to produce students with the same skills. They equated technology skills with twenty-first century skills. Now, although there is a definite connection between technology and twenty-first century skills, technology efficacy is only a small piece. Simple exposure and encouragement will likely not be enough to provide a successful twenty-first century student. Some studies focused instead on the tools to measure the efficacy or attitudes towards science, technology or STEM (science, technology, engineering and mathematics). Unfried, Faber, Stanhope, & Wiebe (2015) developed and validated surveys given to students at different grade levels to determine their attitudes and thus their likelihood of studying or moving into a STEM related field. Identification of such attitudes may provide insight into student abilities or interests, but there are many factors that contribute to student efficacy, and the transferability of this survey in order to compare several different schools did not seem to be a fit with the current study.

Other methods have also been identified as being effective in terms of students gaining twenty-first century skills such as learning by teaching, as demonstrated in a case study conducted by Aslan (2015). Although the results for this study were positive, the sample used was of pre-service teachers and thus the generalizability of this study may not be specifically relevant in supporting the current study that focused on student learning and impact on teacher methodology.

Brain-based educational research has shown that successful student performance is related to teaching methods that utilize brain-based learning strategies. So, it seems that the question is, what do these environments and this methodology look like? Teaching and

learning have the potential to be transformed when these critical elements are incorporated into a classroom. As discussed earlier in this chapter, SmartLabs® incorporate all three critical elements as laid out by Caine et. al. (2009); include relaxed alertness, orchestrated immersion in complex experience (OICE), and active processing of experiences. If students are to become capable, creative problem solvers, they must be able to be able to collaborate, and to efficiently and effectively communicate. Brain-based learning tells us that students that work in environments where they are engaged (i.e. hands-on, problem-based activities), tend to incorporate these experiences into memory more readily then through passive listening (Caine et. al., 2009). According to GÖZÜYEŞİL, E., & DİKİCİ (2014), those students in environments that supported twenty-first century learning performed better academically.

Synthesis of the Review of the Research

The literature review provides some evidence into the issues that rural states confront in terms of providing equity and choice to their students. Research shows support of the design of SmartLabs® and how students learn in the SmartLab® environment in terms of twenty-first century skills as well as the role of the facilitator in the SmartLab® environment. The social constructivist learning theory, along with the research that has been conducted on constructivist learning environments help to further build the case supporting design and application and again the role of the teacher as a facilitator and the importance of an interactive and social environment that is student centered. The learning focus in a SmartLab® are twenty-first century skills. Twenty-first century skills have been extensively categorized, defined and measured and research has supported that they are critical to student success.

This study was both qualitative and quantitative. Qualitative methods allowed for exploration into the experiences of students and facilitators to determine impact. Interviews

and focus groups were useful as they allowed the researcher to examine the perspectives of the two groups (students and facilitators) that may not be obvious or evident elsewhere. The quantitative component of this study measured student learning using a pre-and post-assessment of twenty-first century skills assessment at the beginning of the school year and then again at the end. This assessment was useful to gauge differences that may exist in the development of twenty-first century skills where the SmartLab® is the only identifiable variable that could influence the student scores.

Summary

This chapter begins by identifying the digital divide that exists in the state of North Dakota supported by the teacher shortage crisis and funding challenges. SmartLabs® implementation may play a role in providing equity across the state using state agency support and current school staff to meet the needs of learners. Twenty-first century skills have been acknowledged as critical to developing successful twenty-first century learners and the students' development of these skills is central in the SmartLab®. Learning in the SmartLab® is based on the social constructivist learning theory and the design and methodology including models of teaching, are supported in literature as valuable in student learning and development of students as learners. Furthermore, the learning theory and its application is reinforced by the leadership in the state of North Dakota as a desired pathway to student learning in the state. Below the reader can find clarifications and definitions for the use of some of the terminology throughout the chapter.

Definitions

SmartLab®: A hands-on, project-based, blended learning environment that incorporates online curriculum, projects, facilitator training, technology support and portfolio-based assessment.

Turn-key: A term used to describe an all-inclusive environment. In terms of SmartLabs®, it indicates that the environment that includes computers, hardware, software, kits, curriculum, assessment templates, teacher training and technology support

SMART goal: A goal that is student developed that is specific, measurable, attainable, realistic and time based.

Rural Schools: **"**Rural schools are generally smaller and geographically isolated compared to urban schools. In addition, rural areas differ demographically and economically from urban areas." (Kristiansen, 2014, p.680). A small community, typically with one K-12 school that is geographically removed from major urban communities.

CHAPTER 3. RESEARCH METHODS

Introduction

A mixed-methods approach with a pre-post quantitative and qualitative analysis was used to investigate the impact of SmartLab® implementation in four rural schools in North Dakota. The mixed-method methodology was chosen due to the strengths it portrays, as evident from the analysis of Symonds and Gourd (2010). One of the strengths that supported a mixed methods methodology discussed by Symonds and Gourd (2010), included triangulation of data. "Triangulation is seen to increase validity when multiple findings either confirm or confound each other (thus reducing the chances of inappropriate generalizations)" (Symonds & Gourd, 2010, p. 129). Using multiple types of measures to answer a question has the benefits of removing or limiting any bias that may exist. It would have been impossible to gain full perspective of impact of the SmartLab® using only test scores, interviews, or focus groups alone. It was imperative to understand the impact from multiple angles. According to Greene, Caracelli, and Graham (1989), mixed methods are appropriate under five different circumstances. First, when researchers would like to triangulate or provide a more complete picture regarding a specific topic, also when the researcher would like to complement, elaborate or clarify the results of another method, when using results from one to inform about another as in the case of measure development, when looking to discover paradoxes or clarify inconsistencies from another method with the possibility of reframing research questions, and finally when expanding or looking to provide a more in depth understanding (Greene, Caracelli, & Graham, 1989).

In this analysis, interviews were conducted with two facilitators of the SmartLabs® both at the beginning of SmartLab® implementation in the fall of 2018 and again at the end of

the school year in the spring of 2019. All four schools were geographically isolated, and each was at least 150 miles from the researcher. Two facilitators were chosen (one from each of the K-12 schools), to interview. A series of approximately ten questions were asked in both the fall and spring. A list of the questions asked can be found in Appendix A. Furthermore, a quantitative comparison of test scores, to determine a relationship between the use of the SmartLab® and the scores was conducted (using the Digital Literacy Assessment (DLA)). In this case, using multiple groups (four schools) that have SmartLabs® and determining if participation in the lab (categorically speaking) had affected the students test scores.

In addition to facilitator interviews, student led focus groups were also used at two of the four schools involved in this study. The students that participated in the focus groups were from one of the K-12 schools and the other from a 7^{th}-12^{th} grade school. The fourth school in this study had a very low student population with a combination of only six students in the fourth and fifth grade (a combined class). The fourth school was also located 250 miles from the researcher and was thus not included in the qualitative portion of this study.

Focus groups were used to investigate the impact the SmartLab® has had on the students in terms of how they learn, how they approach problems, and their overall confidence in guiding their own learning. Both focus group interviews were performed in the spring 2019. I believe that focus groups could be beneficial to determine student impressions or perspectives of the overall impact the SmartLab® has had on their learning. There were a series of ten questions asked (Appendix B) with six students from School Two and ten from School Three (Table 2.) Participants at each school were selected using convenience sampling and based on their free hour aligning with the visit of the researcher. The protocol suggested by Kruger and Casey (2001) provided guidance and best practices including ideal the number of participants

and best environment to conduct the group for best results. My belief is that interviews used in conjunction with focus groups allowed for a more comprehensive understanding of the influence SmartLabs® had on the school.

Analysis

Qualitative analysis consisted of transcribing interview and focus group recordings and coding and analyzing them for patterns and significance.

Quantitative analysis on learning was measured using student pre- and post-scores from fall and spring standardized tests, in addition to their scores on the twenty-first century skills assessment (DLA). As previously mentioned, the DLA is a validated instrument that measures twenty-first century skills. Again, both were administered in the fall of 2018 and again in the spring of 2019. Using a paired T-test analysis, the SmartLab® group's performance scores from both pre-and post (for both tests) were compared looking for change.

Participants

School Descriptions. There were four schools that participated in this study. Each was a rural school in the state of North Dakota, located at least 50 miles from the closest urban city. The overall populations of the towns were very small, and most school buildings were built in the early 1900's. There was however a great deal of community support and overall comradery as the school is often the central hub for each town. The integration of a SmartLab® was a great achievement for each school and the pride and excitement for its installation was very evident to the researcher. The integration of a SmartLab® into a 100-year-old school seemed to change the overall atmosphere of the school. A great deal of time is spent in the schools in terms of sports, community celebrations, and in some cases a location for access to technology.

School One. School one is located approximately fifty miles east (about an hour drive) from the nearest urban city that has approximately 47,000 people. The town in which school one is located has a population of approximately 269 people (U.S. Census Bureau, 2019). The high school is located in this town, and the elementary school is located approximately ten miles away. Students are bussed from the elementary school to the high school daily to participate in the SmartLab®. The school building is very large and was originally built in the early 1900's. The K-12 student population is 165 students (Table 2).

School Two. School two is in a rural community with a population of 130 people (U.S. Census Bureau, 2019), located approximately fifty miles south of the closest urban city that has a population of approximately 15,200 people (U.S. Census Bureau, 2019). This school has a student population of only 37 in grades 7-12 (Table 2).

School Three. School three is in a rural community with a population of 334 people (U.S. Census Bureau, 2019). This community is approximately 70 miles south of the closest urban city with a population of approximately 15,200 people (U.S. Census Bureau, 2019). This school is K-12 and has a student population of 187 students (Table 2).

School Four. School four is in a rural community with a town population of approximately 331 people (U.S. Census Bureau, 2019). This community is approximately thirty minutes east of the closest urban city with a population of approximately 47,000 (U.S. Census Bureau, 2019). The community's only school is an elementary school pK-7 with a student population of 44 (Table 2).

Table 2. *Total School Enrollments/Population*

School	One	Two	Three	Four
Grade Levels	K-12	K-12	7-12	PK-7
Population	187	140	37	44

Research Design

This study was a mixed-methods approach with a pre-post quantitative and qualitative analysis. Four schools in the state of North Dakota that have implemented the SmartLab® in the fall of 2018 were included in this study. Participants were students and teachers (referred to as facilitators) from grades four through eight.

The qualitative component of this research consisted of fall interviews with two facilitators at two schools which were selected due to the school's student K-12 population. Follow up interviews were conducted in the spring with the same facilitators. This was done to further investigate the perspectives of facilitators and identify if there are any self-identified changes in their teaching methods and if they have witnessed any differences in students that they would attribute to the SmartLab®. An interview protocol was used during the interviews (See Appendix A.).

The quantitative component of this study included administering a pre-and post-assessment (DLA) to students from all four participating schools.

Sample

Four schools that implemented a SmartLab® in the fall of 2018 were included in this study to increase the sample size, and to provide a better picture of the impact on schools from different parts of the state. Furthermore, representation from all four schools provided data

from both elementary as well as middle school students and teachers.

The instrument that was chosen to measure twenty-first century skills (DLA) had two options. The first, an elementary option geared towards 4-5th and the second a middle school option 7th-8th grade. The grade levels of the participants can be found in Table 3.

Table 3. *Grade level of participants measured using the DLA*

**students that completed the pre and post.*

	School				
Grade	One	Two	Three	Four	Total
4th	0	8	NA	4 (*3)	12(*11)
5th	12 (*11)	0	NA	2 (*1)	14 (*12)
6th	0	8 (*6)	10	0	18(*16)
7th	0	0	5	0	5
8th	10 (*9)	7	0	0	17(*16)
TOTAL	22 (*20)	23 (*21)	15	6(*4)	66(*60)

All four schools participated in the pre- and post-tests for both twenty-first century skills (using DLA) and analysis of individual standardized test scores. In addition, the researcher made site visits to all schools involved.

Regarding external validity, the schools that were selected due to their implementation of a SmartLab® are a good representation of rural schools in North Dakota. The results will thus be generalizable to other rural schools that implement the SmartLab®.

PROCEDURES AND TIMELINES

Data collection for this study occurred in two stages. Stage one occurred in the fall of 2018, and stage two in the spring of 2019. (Table 4)

Stage one. Stage one included school visits to all four schools participating in the study. During the visits, the researcher administered a Digital Literacy Assessment (DLA) to those

students that have been, or will be, exposed to the SmartLab® during the school year. Grade levels five and eight were initially chosen for data collection, but due to the low school populations and in order to increase the sample size, students from fourth through eighth grade were included contingent on their SmartLab® participation during the 2018-19 school year.

Preliminary teacher interviews were conducted at two schools with teachers that had been trained as facilitators in the SmartLab®. It is important to recognize that both facilitators were fully trained and certified to facilitate in the SmartLab®. All public information including school size and grade level sizes were accessed from online state longitudinal data system for **Stage two.** The second stage of the research occurred in the spring of 2019 and consisted of a return visit for follow-up interviews, and post-test administration of the DLA. Again, public information was accessed from online state longitudinal data system for all schools and grade levels involved in the study. Student focus groups were conducted during this stage at schools Two and Three.

Table 4. *Methods of Data Collection*

Schools	Methods of Data Collection (What is being measured)	Implementation (Fall 2018, Spring 2019, or Both)
All Schools (1-4)	Twenty-first Century skills Technology Literacy (Student learning; Digital Literacy Assessment)	Both
1 & 2	Teacher Interviews (Teacher Perspective)	Both
2 & 3	Student Focus Groups (Student Perspective)	Spring 2019

Control of internal validity. Randomization and non-manipulation of the independent variable is a threat to internal validity. The schools that installed labs were chosen due to school administration deciding to implement SmartLabs® during the specific time that this study was to be conducted. It is reasonable to conclude that one rural school, in the relatively rural state of North Dakota, will have a similar population and characteristics as another school. Mortality was an internal threat and was addressed upfront by explaining completely the value and importance of completing the study. All collected data was conducted by one individual and therefore, the data collector threat was addressed.

Data Instrument. The quantitative data instrument that was used in this study was the Digital Literacy Assessment (DLA). Learning.com (2018), the creators of this assessment, explain that this instrument has been "designed to evaluate student proficiency in twenty-first century skills described by the ISTE standards. The assessment is aligned to all 24 standards in the

following six areas, creativity and innovation, communication and collaboration, research and information fluency, critical thinking, problem solving, and decision making, digital citizenship, technology operations and concepts" (personal communication, October 11, 2018). In addition, it has received the ISTE seal of alignment. The alignment and process are described as:

> Products and resources submitted to the ISTE Seal of Alignment program undergo a rigorous review by a panel of subject matter experts who have a deep understanding of the ISTE Standards. Resources and solutions seeking the ISTE Seal of Alignment are evaluated based on their pedagogical value and the extent to which they build the skills embodied in the standards (Learning.com, 2018).

Furthermore, the International Society of Technology in Education (ISTE) concurs, stating that:

> The ISTE Seal of Alignment program recognizes edtech products for their alignment to the ISTE Standards. When you see the seal, you'll know the resource or tool provides a high-quality, standards-aligned learning experience that enhances students' digital age skills.

There were two separate assessments that were available, one designed for elementary, and one designed for middle school. The proficiency level for the elementary school version is at fifth grade and for the middle school the version is eighth grade. This will be examined in greater detail in the following section. The assessment is given in two parts and should be administered over two 45–50-minute sessions. Learning.com (2018) described this assessment as including a "psychometrically validated blend of interactive, and performance-based questions that allow students to authentically perform complex tasks in simulated applications,

and knowledge-based, multiple choice questions". (personal communication, October 11, 2018).

The Digital Literacy Assessment (DLA) was a cumulative assessment designed to measure all concepts that students should have mastered by the end of elementary (5th grade) or middle school (8th grade). There were approximately eight questions per standard that address the overall ISTE standard and indicators that accompany that standard (Appendix D). There were a variety of items and question types to mimic state online assessments, including items with multiple questions, multi-select questions, and several different interactive question types.

Teacher interviews to gauge teacher attitude or perspective regarding impact were conducted and recorded. Finally, student focus groups were conducted and recorded to gauge student attitudes and impressions and their perspectives of the impact of the SmartLab® on their learning.

Analysis

Quantitative. The pre and post test scores were compared to calculate the gain score. The improvement or gain from pretest to posttest was calculated for each participant by subtracting each students' pretest score from their posttest score. A positive gain score indicated that the posttest score was greater than the pretest score and a negative gain score indicated that the posttest score was less than the pretest score. Furthermore, a paired two-tailed t-test was conducted with the pre-post test scores collected from the DLA. The purpose of the test was to determine through statistical analysis that the mean difference between paired observations in this case, pre and post tests on a DLA were significantly different from zero. I hypothesize

that there will be significant increase between mean scores from pre and post assessment scores.

Qualitative. The teacher interviews and student focus group recordings were transcribed using Temi® a transcription software and then verified by the researcher. The transcripts were then coded and analyzed for patterns and significance. The researcher analyzed each interview and focus group and then cross analyzed the data.

Human subject approval

Ethical Considerations. As a state employee, I do have an interest in the implementation and success of the SmartLab® initiative in North Dakota schools. As a part of my position, I do play an integral role in the installation, and training of facilitators. I do not however feel that I, as a researcher, am in a position of power or authority over the participants. I did not train the facilitators that were interviewed, for the purposes of this study, in the SmartLab® environment. As an adult and as an outsider there may have been hesitation on the part of the students. This was especially prevalent due to the rurality of the schools which further identified me as an outsider. I attempted to alleviate this by explaining the importance and discussing with the students prior to the data collection that there would be no impact on their grade.

It was very important to establish a connection with the school and develop a rapport with the participants. I spent several days in the school due to the lab installation and training, and research for data collection and therefore became somewhat familiar to the students. The return visits to the schools throughout the year to conduct observations and interviews likely contributed to being more generally accepted by the students and the staff as I was familiar. This was evident when I was greeted by students by name and was invited to sit with them

during lunch.

The only potential source of harm to participants that exists in this study is the possible anxiety that may occur when students are asked to complete the digital learning skills assessment. It is possible that students felt anxious and concerned with their success on the exam. I feel that providing them with the assent form and introducing myself to them helped to alleviate the possibilities of harm. I was sure to address the fact that the student's grade and/or standing in the classroom was in no way affected by their participation in the study.

Consent. Gaining parental consent was challenging due to the geographic distance between the researcher and the participants and privacy in obtaining parental contact information. Because the students were under 18, parental consent was required and obtained through two different methods. First, an Office365® Form was emailed to each parent via the school administration to attempt to gain electronic permission. If the first method failed, the second method was used, a consent form was emailed to the facilitator and then sent home with the student. When returned, the forms were collected by the facilitator and given to the researcher.

Confidentiality. Confidentiality was maintained by using codes to represent schools, students and teachers. Names will only be visible for organizational purposes and only to the researcher. No one else will have access to this information. The student and instructor interviews that were conducted were recorded and transcribed, if the recording includes any names they were stricken from transcript. Upon completion of the study all recordings and any names kept for organizational reasons were deleted or destroyed.

Summary

The research was conducted using a mixed-methods approach with a pre-post quantitative and qualitative analysis. The qualitative component of this study included interviews which were conducted with two facilitators from four schools with SmartLabs® included in this study. The facilitators were chosen due to the population of K-12 students in their schools. Two focus groups with students from two schools were also conducted using convenience sampling and at the SmartLab® locations that were reasonably close in proximity to the researcher. The quantitative component of this approach consisted of the pre and post assessment of twenty-first century skills (DLA) and collection. Quantitative analysis will consist of comparisons between pre and post test scores, looking for the mean difference between paired observations in this case, pre and post tests on a DLA to determine if they were significantly different from zero. My hypothesis was that there was significance in the mean score difference. Qualitative data was transcribed, coded, analyzed, and themes and patterns identified. Through a cross analysis of data, I hoped to identify if there was an impact due to SmartLabs® in terms of student learning and student and teacher perspectives.

CHAPTER 4. RESULTS AND ANALYSIS

Introduction

In 2014, the state supported virtual school, North Dakota Center for Distance Education (NDCDE) that I work for began the process of providing twenty first century learning environments (SmartLabs®) for K-12 schools across the state of North Dakota. The mission of NDCDE includes providing educational opportunities to all students in North Dakota regardless of their location. Some North Dakota schools struggle to provide project-based learning environments that are inclusive enough to support content, assessment, materials, and training. This is often due to teacher shortages and inadequate funding for new initiatives. SmartLabs® Provide the essential components to allow any school, regardless of their location, staffing, or technology skills, and funding (due to financing option and reduced price) the opportunity to offer project-based learning environments in the form of SmartLabs® with support from an educationally based state agency. The goal is to assist schools and support teachers while providing students with learning environments that cater to the development of twenty-first century skills.

My background in science, fifteen years' experience teaching, and six-year experience in facilitating the implementation of hands-on environments, made me uniquely qualified to explore the topic of the impact these environments were having in the schools that had implemented them. I provide a unique perspective with my background, experience, research, and site visits of SmartLabs® across the country. In addition, in my visits, I have received anecdotal reports of the positive effects of SmartLabs® on students and teachers, which provided further motivation to conduct this study. Ultimately, the data from this study may

provide the state with what it needs to make the decision to conduct statewide implementation of SmartLabs®.

Conversely, my fundamental role in the installation of SmartLabs® and training of facilitators in these environments over the past several years could be perceived as a potential for bias in my interpretations. In an attempt to counter this possibility, I was very conscious of remaining as objective as possible through the data gathering and analysis portions of my research. To remain objective, I was cognizant of my reactions to answers provided to my questions from both facilitator interviews as well as student focus groups. During my explanation of the process and in the consent forms for both interviews and focus groups, I articulated the value in open honest answers whether supportive or non-supportive of the SmartLab®. During my analysis, I was careful to not assume meaning regarding answers to questions using only responses and notes I had made throughout the data collection events.

The purpose of this research was to explore the impact on student learning and teaching that the implementation of a SmartLab® had on four rural schools in the state of North Dakota. As discussed in both chapters one and two, there is a digital divide that exists in largely rural states. It was of interest of the researcher to determine if there was an impact on the students and teachers, and if there was, what was impacted. The lens that was used for data collection was the view from the perspectives of both the students and teachers from four rural schools. This research project had one guiding research question with multiple components. The guiding research question was:

What is the impact of a SmartLab® implementation on students and teachers in a rural school? Impact was measured in terms of student learning, teacher perspective and student perspective.

- Student learning (twenty-first century skills)

- Student perspectives
    - How/if their learning has changed.
- Teacher perspectives
    - How/if student learning has changed
    - How/if their teaching has changed

To answer the question of student learning, pre and post-test scores were collected using a validated twenty-first century skills assessment instrument called the digital literacy assessment (DLA). To gain teacher perspective, semi-structured teacher interviews were conducted with two teachers (known as facilitators) from two of the four schools included in this study. The facilitators interviewed from two of the four schools were chosen for the following reasons:

1. They were the lead of the facilitators at their respective schools
2. The schools were in reasonable traveling distance to the researcher
3. Neither were trained in the environment by the researcher
4. Both were located at K-12 schools.

The student perspective was acquired using two student focus groups conducted at two of the four schools included in this study. Focus group A interviews were conducted at a K-12 school and focus group B occurred at a grade 6-12 school. The student groups were primarily selected based on their availability during the school day and their availability during the time approved by the administration. Focus group A consisted of an entire sixth grade class of ten students. Focus group B consisted of six students from grades 6-12 that were selected based on their availability during the approved time with effort to have representation from multiple grade levels. Due to the small size of the school population (see Table 1), student availability was used to increase the number of contributing participants.

Sample descriptions

Qualitative sample description

The qualitative sample consisted of pre (fall 2018) and post (spring 2019) interviews with two facilitators and one session student focus groups conducted in the spring of 2019 with two groups of students from different schools. Both facilitators were trained to work in the SmartLab® environment in the summer of 2018. The researcher trained neither of the participants and the facilitators had no previous experience in a SmartLab® environment prior to their training. The two focus group sessions were held in the spring of 2019. In order to gain the true perspectives of the students, it was important to interview them after they had experienced participation in the SmartLab® for the entire school year. Both group participants were selected based on their participation (access) to the SmartLab®, and their availability during the times the researcher visited their school. The names of the facilitators interviewed, and the names of the schools have been changed to maintain confidentiality.

Facilitator interview participant descriptions

Kathy

Kathy is a Caucasian female in her early 30's that was originally from Montana. She completed her educator studies in the state of North Dakota in the areas of science and engineering. She had previously been a science and health teacher for grades seven through twelve at a school in North Dakota but became unhappy and dissatisfied with her position. She felt the school was "moving backwards" after budget cuts for labs and other science related materials occurred. She also shared that she began feeling discontented with her autonomy and ability to provide the level of education she felt was best for her students. She explained, "I was looking to move out of the school I was in, they were moving backwards in my opinion." Upon hearing about a position at her current school from an in-district teacher, and with

assurance from administration that they desired innovation and forward thinking, she moved to rural North Dakota and accepted a sixth-grade teaching position.

Donna

Donna is a Caucasian female in her mid-30's and grew up in the community where she taught. Donna has extensive experience in education working as a pre-school teacher for ten years. She was pursuing a teaching license during the time of the interview. Donna was very excited with the prospects of becoming a science teacher and seemed delighted with the utilization of the SmartLab®. Donna was somewhat nervous about working in a SmartLab® environment mainly due to classroom management and lack of content knowledge. She explained "I have never really been in charge of a science classroom per se…I am not like the math teacher or an English teacher...So I really sometimes struggle with the classroom management part of it".

Focus groups sample descriptions

Focus Group A

There were 10 student participants in the focus group in focus group A. All participants were in the sixth grade. All participants were Caucasian. There were six female and four male participants.

Focus Group B

There were a total of six student participants in focus group B. The students represented nearly every grade level in the school (one sixth grader, one seventh, one sophomore, two juniors, and one senior). All participants were Caucasian. There were four female participants, and two males.

Quantitative sample description

There was a total of 60 student participants who completed the pre and post Digital Literacy Assessment (DLA). Student participants were selected based on SmartLab® participation and grade level. All students between grades three through eight that had spent time in the SmartLab® were requested to participate. There were two versions of the DLA used. One dedicated to elementary students and one to middle school students. Each of the versions measured the same skills grounded in the ISTE standards (see Appendix D) at the relevant grade level. Version one was designed for elementary students and Version Two for middle school students. Student participants who took Version one was in grades three through five and those completing Version two were in grades six through eight. There were six student test results eliminated from the data collection due to a failure to complete the post-assessment due to absence from school the day the assessment was administered.

Research Methodology Applied to the Data Analysis

The results of data analysis are presented in three sections in this mixed-methods study. Qualitative results were gathered from data collected during one on one interviews with SmartLab® facilitators and focus group interviews with student participants. Qualitative results are combined with quantitative results that compared scores on pre-test and post-test digital literacy assessments. Quantitative and qualitative results were then compared to aid in the interpretation of results with respect to the research questions. The research questions that were under examination are restated below to provide a focus of the results. As a reminder, there was one overall research question that had multiple sub questions.

What is the impact of a SmartLab® implementation on students and teachers in a rural school? Impact was measured in terms of student learning, teacher perspective and student perspective.

- Student learning (twenty-first Century skills)
- Student perspectives
    - How/if their learning has changed.
- Teacher perspectives
    - How/if student learning has changed
    - How/if their teaching has changed

This study utilized the mixed-methods approach. The decision to use the mixed-methods approach was based on the researcher's belief that student learning and teaching method impact could not be addressed qualitatively or quantitatively exclusively. The research questions are multi-dimensional and to answer the them completely it was important to not only have a testing sample, but also to gain perspective of both students and teachers to provide a complete picture. The four-way categorization of mixed methods designs developed by Creswell and Plano Clark (2007) include triangulation, embedded, explanatory and exploratory. This study utilized the triangulation mixed-method design. The intention of this design was to corroborate data from multiple perspectives; in this case the teachers and students to provide depth of understanding of the impact of the SmartLab®. Furthermore, to use an assessment to provide another form of data to deepen the understanding of impact provided an opportunity to use triangulation. Denzin' s 2006 study (as cited in Fusch, Fusch & Ness, 2018, p.26) stated that triangulation is the method in which the researcher "must learn to employ multiple external methods in the analysis of the same empirical events". The use of triangulation during interpretation allows the researcher to "explore different levels and perspectives of the same phenomenon…and is one method by which the validity of the study results are ensured" (Fusch, Fusch &Ness, 2018, p 26).

The four of Denzin's types of triangulation identified as "data triangulation for correlating people, time, and space; investigator triangulation for correlating the findings from multiple researchers in a study; theory triangulation for using and correlating multiple theoretical

strategies; and methodological triangulation for correlating data from multiple data collection methods."(Fusch,Fusch,& Ness, 2018, p.22). This study utilized methodological triangulation. Methodological triangulation can include data from one method known as within method (i.e. qualitative only) or can be a combination of quantitative and qualitative techniques known as between-method (or across method) triangulation (Fusch, Fusch & Ness, 2018). Across method was identified as the ideal application of this form of triangulation to account for flaws and deficiencies with a goal to understand the phenomenon, not necessarily to enhance the validity (Fusch, Fusch & Ness, 2018). This study utilized across method triangulation including data from a qualitative perspective (interviews, and focus groups) as well as quantitative (pre and post test scores from the DLA). The goal of using this mixed methods form of methodological across method triangulation was to understand and identify the phenomenon, in this case the SmartLab® impact, the data was sufficient to be used to corroborate findings from both the qualitative as well as the quantitative perspective (Fusch, Fusch & Ness, 2018).

Presentation of Data and Results of the Analysis

Qualitative Results

Analysis of qualitative data

Student perspectives and teacher perspectives about their learning and teaching were measured using qualitative interviews and focus groups. Using semi structured interviews (Appendix A) and semi structured questions for the focus groups (Appendix B), participants were asked open-ended questions to ascertain as much detail as possible about their experiences. Interview and focus group sessions were recorded and then transcribed using Temi® a transcription software. The researcher listened to each audio recording at least twice while comparing the transcript to check for errors. Each transcript was read thoroughly multiple times using the research questions to focus the analysis on the perspective of either the

students or the facilitator in terms of student and or teacher perspective of impact. The researcher used Creswell's (2005) six-step approach for data analysis for both the interview and focus group portions of this research. Creswell's (2005) six-step approach for analysis discussed in more detail below. After reading through the transcripts many times, the memoing process began where various thoughts and ideas were written in the margins of the transcripts. Throughout the memoing process, various codes began to emerge. The codes were analyzed for accuracy, then were organized into themes. This painstaking process took many days to complete and only when all the codes were organized under the proper theme did the researcher stop the analysis process.

Focus group design and the protocols used was managed using Krueger and Casey's (2000) guide to developing and conducting focus group interviews. Included in the focus group design was the use of the suggested categories and characteristics to include for successful focus group facilitation. The categories included participants, environment, moderators, analysis, and reporting.

Krueger and Casey (2000) suggest that participants should include five to ten participants (six to eight preferred) and be similar types of people. Krueger and Casey (2000) also suggest that the environment where the focus group sessions are conducted include comfortable, circle seating and that it should be recorded. I included each of these requirements in the conduction of the focus groups for this study. Krueger and Casey (2000) also suggest that the moderator be skilled in group discussions, use pre-determined questions, and establish a permissive environment. All requirements were met in the utilization of the focus groups for this study. Finally, in terms of analysis and reporting, Krueger and Casey (2000) suggest that there should be systematic analysis, with verifiable procedures and

appropriate reporting. As stated previously, this requirement was met using Creswell's (2005) six-step approach for analysis which is discussed in more detail below.

Qualitative research studies involved a continuous interplay between data collection and data analysis (Strauss & Corbin, 1998). For this reason, I began analyzing data following the interviews to begin identifying patterns, and to facilitate subsequent data collection (Strauss & Corbin, 1998). Qualitative analysis is a form of intellectual artistry. There is no single way to accomplish qualitative research, since data analysis is a process of making meaning. It is a creative process, not a mechanical one (Denzin & Lincoln, 2003). Similarly, a qualitative study capitalizes on ordinary ways of making sense (Stake, 1995). Stake reminds qualitative researchers that, "there is no particular moment when data analysis begins. Analysis," he explains, "essentially means taking something apart" (p. 71), which in this case, not only means understanding the ways teachers use and make sense of SmartLab® technology, but also identifying and defining the patterns that emerged from that meaning making process. Qualitative data analysis, then, gives meaning to first impressions and final compilations. It is an analysis that tells the story of teachers' intentions to make (and their results from making) informed decisions that define and guide their use of SmartLab® technology in their classrooms.

Methodologically, Esterberg (2002) suggests, "getting intimate with data" (p. 157) and describes the main objective of immersing oneself in interview transcripts to "load up your memory" with the collected data. This dissertation research followed the data analysis and coding procedures suggested by Creswell (2005) and Esterberg (2002). Specifically, Esterberg (2002) suggested that open coding is a process where "you work intensively with your data,

line by line, identifying themes and categories that seem of interest" (p. 158). Memoing, or writing small notes in the margins were also utilized during the data analysis process.

Additionally, Creswell (2005) mandated the traditional approach in the social sciences that allows the codes to emerge during the data analysis (p. 187). Once the data from this research were examined thoroughly through the open coding process, I reviewed the codes for emerging themes in the data.

This research study followed the Creswell's (2005) six steps during the data analysis process and, although these steps are described in linear order, Creswell described "an interactive practice" to analysis. That is, there is a recursive element to following these steps—the process is not simply a static, linear order of analysis.

Step 1: Organize and prepare the data for analysis (p. 185). During this step, I reviewed audio tapes from interviews and transferred them into word document transcripts.

Step 2: Read through the data (p. 185). This step also aligns with Esterberg's directive to "get to know your data". I reflected on the overall meaning to gain a general sense of the information and ideas that the participants conveyed. It was during this step that memoing occurred.

Step 3: Begin detailed analysis with the coding process (p. 186). I followed Creswell's procedure of organizing the material into segments by taking the text data and segmenting sentences into categories. I then labeled those categories with terms based on the actual language from the participants.

Step 4: Use the coding process to generate a description of the setting or people as well as categories for these for analysis. (p. 189). I used this process to generate codes for the descriptions, which then led to generalizing a small number of categories or themes. Then, I

analyzed the themes that emerged and gathered the various cases into a general description for this bounded case.

Step 5: Advance how the description of the themes will be represented in the qualitative narrative (p. 189). For this step, I wove the emergent themes into narrative passages, so that the findings emerged logically from the participants' responses.

Step 6: Interpret the meaning of the data (p. 189). Creswell recognizes that a researcher's own background plays just as important a part of the meaning making process as a researcher's fidelity to a theoretical lens. During my own interpretation process, my experience as a former high school teacher informed my understanding of the participants' stories. As well, to convey the participants' perceptions of their experiences accurately, I focused specifically on what they were saying, the conclusions they drew, and their intentions for future practice. The themes that emerged from this study came directly from my awareness of the healthy tension between my own biases and the participants' own meaning-making processes.

Interview analysis (Teacher Perspective)

Two interviews were conducted with the teachers. One was administered in the fall 2018 and the second in the spring 2019. The rationale for two interviews was to identify any emerging or new outcomes that occurred throughout the course of the year. Any identified changes from the perspective of the facilitator were noted and reported. There were two noticeable differences in comments from fall to spring; the role of the facilitator in the transition from a direct instructor methodology to a facilitator mindset or methodology, and student learning. This will be discussed in more detail below. Again, the analysis was focused using the lens of potential impact due to SmartLab® implementation on teachers in the school

(including the interviewee), as well as the teacher perspective of the impact that the implementation had on the students. Other impacts were identified through the interviews that included impacts on and from administration and the community.

Kathy

In the fall of 2018, Kathy discussed student needs in terms of the limitations that existed for the students due to their location. She explained how the SmartLab® is helping to make a difference in providing and supporting the needs of their students. She discussed the support of the school to provide technology prior to the SmartLab® implementation but indicated that the activities they were able to do in the classroom were far more limited until they had access to the SmartLab®. Kathy made the following comment as it relates to student needs:

> We had talked about, with the technology committee, which I am a part of…. We have one to one devices for all of our students. And so, every student here, kindergarten through 12th grade has their own laptop….and so (currently) we can do research projects. We go online and do different, simulations for science, (but there are) like projects that we can't do here…they've done some different, like Skype interviews with scientists.

When discussing the impact that the SmartLab® has had on how she teaches, or any noticeable differences in other teacher's methods, she mentioned the learning curve that was associated with the implementation of the SmartLab® and the need for teachers to "step out of their box". She explained that the SmartLab® has required teachers to do things differently but in a supported environment with structure, and that the curriculum in the SmartLab® has made

things easier for them. During her spring 2019 interview she made the following comment about the effects the SmartLab® had on her teaching methods:

> The SmartLab® brought the curriculum with it that made stepping out of our boxes and pushing ourselves as teachers, easier to do because it wasn't something that we were going to have to figure out how to incorporate and how to figure out how to teach it and how to figure out, you know, how to get the kids the right directions for everything. And so, having the smart lab is the foundation of that or has been. I don't know, it makes it easier. Makes it, I mean, we're on a path. I think the smart lab just helped us create that base where now we really have things to work with and we have people to turn to and we have better access.

Furthermore, in her spring 2019 interview, she discussed just how different teaching in the lab was from what she had anticipated. She was more hands off than she thought she would be which provided her the ability to work with students individually. She explained:

> It was like way more hands off than I even thought I would have to be. And I was way less available as a resource and making them really search out other people or other places to find that information than I thought I was going to. So, like that, that changed. I guess my perspective of those twenty-first century skills are much more hands off than I thought I was going to need to be.

Needs and opportunities were closely related in the analysis of this data but were distinguishable when considering that needs were referred to as mostly materials, or physical components (or technological access). Conversely, opportunities were things such as access or activities that the SmartLab® was perceived to have opened or offered to the students that they

would not have had otherwise. Kathy discussed the rural nature of her community and how the SmartLab® offered experiences that the students could not necessarily be exposed to prior to having the SmartLab®. An example she gave to the limitations that they encounter was access to experts in multiple fields. She pointed out the hospitals, universities and other businesses in the larger North Dakota communities and in comparison, her community does not have immediate access to these individuals because they are from rural North Dakota. During the fall 2018 interview she discussed the inequality that they experienced, and how the SmartLab®, and the curriculum and connection to others across the state, due to the use of the SmartLab®, has opened doors and offered experiences that students in her rural community would not have had access to otherwise. She commented:

> It's more equitable now than it's been. There's still some things that either monetarily or like expert wise that I know when we were studying and doing stuff for like Science Olympiad where was way out of my depth and so was the other science teacher…like they're doing protein modeling and like with the computer program and having to find where amino acids attached and build a model. And he and I were both a little out of our depths with all of that process to try and find like an expert or someone for them to talk to. It took us a lot more trouble than it seemed like when we talked to some of the bigger schools. And so, like there's some disparity I think still in that arena of like having access to things… (with the SmartLab®) They've gotten to sort of experience things that I wouldn't otherwise be able to even get to. Being in the middle of North Dakota in a very rural, you know, location in a very small community.

The impact on the community and administration were themes that were somewhat unexpected and were a bit outside of the focus of this study but were brought to the surface

during the interviews and are important to assess further. In the spring 2019 interview Kathy mentioned the importance of the "super supportive" community both in terms of community member's interest in volunteering to be in the lab, but also in terms of providing monetary support to purchase additional materials and equipment to support the students. Furthermore, the administration support and perception and the granting of authority and resources were incredibly important. She stated:

> Community is super supportive though. So whatever sort of is needed to help. We've had donations for, different projects and things from the different community businesses. So, building materials and, volunteers that have come in and helped the kids build different projects like solar cookers and so very supportive in that mind, but trying to bring in those communications with other people outside of the classroom and with one another to be able to do.

Student learning seemed to be a huge focus for this facilitator. She discussed first the transition and frustrations that occurred when the SmartLab® was first implemented. She indicated that students were not familiar with this type of learning environment and there was a learning curve that included frustration on both the part of the student and that of the teacher. She did however identify the importance and evidence that the students were gaining the skills that were intended in the SmartLab® which include the twenty-first century skills. During the spring 2019 interview, she commented:

> It took quite a long time because it took them a while to actually get in that mentality of I'm really going to have to try something. I really have to actually, you know, put myself out there and it might not work. And then I have to Redo it and then I'm getting over that initial frustration of, well it doesn't work. I can't do this.

> I just remind myself that it's better for them… cause you want to help them, you know, like you want to help kids.

She continued:

> We just did our state testing and like our NWEA testing and our science scores and our math problem solving, and the reasoning areas are up leaps and bounds over where we started and even like from winter (2018) to now (spring 2019) has been like, there's, there's huge increases in so many of my kids, like all of them showed increase, but there's, you know, progress. But some of them have just almost found like a new confidence in their ability.

Her final thoughts from the spring 2019 interview on the SmartLab® and the impact that it has had are summarized in the following quote. The impact that the SmartLab® has had on students and teachers has been overall positive and her feelings of its positive impact are evident.

> I'm glad that we have brought it in. I think that it's a tremendous opportunity for the different kids and the different levels…. I love that it challenges, you know, the middle school and high school kids to really get out of their comfort zone. So, my feelings are that, you know, I'm really glad that it's here. I'm glad that it's pushed some of us out of our comfort zone to be a facilitator like a guide for them in their learning, you know, instead of direct instruction all the time.

Kathy expressed both positive (i.e. student independence) and negative aspects (learning curves and frustrations) of the SmartLab® during her spring 2019 interview, but in terms of

overall impact each identified theme showed that there was a positive impact by the implementation of the SmartLab®.

Donna

Donna's focus in terms of student needs was very similar to that of Kathy, and she gave very specific examples of activities that students can only do now that they have a SmartLab®. When discussing a typical classroom assignment, she said:

> I think it's just the whole idea of the SmartLab® and having new technology and having all of these different programs (software) available. When a teacher says 'Hey, we're reading these stories' and I am like 'Hey, let's turn them into a comic book…or into a movie…or build with our hands.

She also discussed the limitations the school has in terms of hiring staff. Due to the rural nature of this school, and even though she does not hold a science teaching license, the administration chose her to facilitate in the SmartLab® due to her experience teaching in preschool, and their lack of other options. She explained that the superintendent had chosen her to work in the SmartLab® because she was the best option because of her willingness to learn. Donna's placement in the SmartLab® was important as there are many schools in the state of North Dakota that may be in similar situations of wanting to innovate and offer technology-based opportunities to students such as the SmartLab®, but with the existing teaching shortage, utilizing existing staff must be an option.

She explained that she speculated that she was chosen to facilitate because:

> …maybe due to my taking online college classes and so I'm already frequently familiar with a lot of the technology, um, and with my own kids and with the kids, you know, I feel like I have a pretty good relationship with them. So maybe understanding a lot of

> the technology that they're going through and that they're using. Maybe that was the helpful.

During the fall 2018 interview, Donna candidly discussed some of her struggles in the SmartLab®, most of which were in relation to her inexperience in classroom management, but also due to her academic credentials. Donna found that the environment allowed for more personal relationships with the students and this increased her ability to relate to them on a one to one basis. In the spring 2019 interview, she did express her excitement for the next school year and shared ideas she had for improvement and expansion. She excitedly shared:

> I just love it. It's so much fun and I just want to get everything for everybody…I brought in my photography studio stuff that I have personally and so I'd really like to get the kids broadcasting something next year. Even if it is not as extravagant as like what the module says, doing something where they can present to the school once a week. This is what is happening (in the SmartLab®), and having the kids be in charge of something like that!

She talked about the learning curve in terms of students and with herself as a teacher. In the spring 2019 interview, she explained "I would say my experience has been just interesting. It's been, a learning curve, not just for the kids, but for me as well…and learning that it's okay for me not to know all the answers." She had concerns regarding content and her ability to answer questions but discovered in her participation in the SmartLab® that in a student-centered learning environment, the teacher is not the content expert, they are more of a guide. She explained in terms of how it usually would be in a traditional classroom:

> …now we have to work on math, and you have to sit there and do this or that. Um, no we're in SmartLab® (It's not like that). They can move around…as long as they stay on pace, I'm not hounding them. It is really less formal.

In the spring, Donna shared that the SmartLab® had essentially transformed her into the unofficial project-based expert at her school where other teachers meet with her and ask her for help with ideas, something that was unexpected. She explained the challenges asserting:

> When I first started I didn't feel very comfortable at all and usually I'm very comfortable around technology, but I was scared and very nervous…now that I have had kind of a year's experience, I feel I understand a lot more of what we are doing and how I can make it different

She further discussed challenges stating that:

> ...sometimes struggle with the classroom management part of it…but it's also nice because I can sit down and I can have those conversations with them during that class period to say, Hey, what are you working on? You know and getting to know them and what their interests are, where a lot of the main teachers don't get to do that. So that to me feels like a huge difference.

An increase in student opportunities was included in much of the discussions with both facilitators, but unlike Kathy, Donna focused on the use of technology as an example of an opportunity that her students would not have had prior to SmartLab® implementation.

> I think it's just the whole idea of the SmartLab® and having the new technology and having all these different programs (software) available. When, when the teacher says, Hey, we're reading these stories, and I'm like, Hey, let's turn it into a comic book. Or

> we're learning about this topic. Okay, let's turn that into a movie, or let's build it with our hands. I think a lot of the teachers are, they're very willing to let me just kind of choose and decide.

Support by the administration was key in the implementation of the SmartLab® at this school. Donna discussed the role the principal had continued to play in the lab in terms of encouragement. She described how the administration had continued to provide resources to the SmartLab® and are providing time and encouragement for the development of new activities, and resources and are supportive to provide opportunities to open the lab to other teachers to provide professional development opportunities. She commented that:

> Our principal and I have been talking about is possibly having a training one day in here… (we have) been really working on trying to get some kind of professional development where we have time to sit and visit about it and help the teachers individually as well as, as a group.

Student learning was discussed in terms of student growth from the fall to the spring. One of the most evident examples of student learning that Donna discussed was the development of student problem-solving skills, and self-confidence. She was impressed with the development of these skills from the fall to the spring. She specifically asserted that,

> The students really, at first, they were really struggling with just trying to problem solve themselves and now they're starting to see that, oh, (facilitator name) isn't really going to be helping all that much. So now they're having to learn what to do in order to do that. …and being okay with can I just go do this or do I have to ask permission to go onto the computer? And it's like, this is your room, use it. And so just that whole self-

> confidence has really helped…I haven't really seen a lot yet other than just their confidence building and their excitement once they get into projects.

Overall, the facilitator interviews provided positive feedback in terms of SmartLab® implementation and the facilitators were able to give examples of how the SmartLab® implementation had impacted the school.

The most prominent themes that were identified during the interviews focused on student needs, the impact on teaching methods, an increase in student opportunities, impact on administration and community, as well as and most specifically, the effect on student learning. Each identified theme is summarized below, and each will be examined in greater detail at the end of the chapter.

Student needs included discussion about technology and potential career exploration. They included the need to provide equitable opportunities to the students from rural schools in comparison to the more urban counterparts in other areas of the state.

Impact on teaching methods focused on the role change and growth in terms of skills in facilitating a project-based classroom on the part of the interviewee. There were some comparisons provided regarding teacher background and methods training (science vs. other disciplines) regarding their transition from a traditional classroom to facilitating in the SmartLab® environment. There were also comments regarding how the SmartLab® provided the teachers a way to offer project-based learning easily.

Both interviewees mentioned effect on administration and community. Administration buy-in and support were identified as very important for the success of new initiatives. The budget and autonomy required to do something outside of the traditional classroom seemed reliant on the administration, and the administrative backing was and became more prominent

as the year progressed. This was evident during the interviews when the teacher expressed the administration planning for future events, and support in holding professional development in the SmartLab®. The support of the community was also discussed in terms of implementing the lab and then supporting the efforts.

Student learning was the most prominent effect discussed during the facilitator interviews. This impact included comments regarding the opportunities for student authentic learning where they designed and implemented projects. Furthermore, from the teacher/facilitator perspective, student confidence, perseverance, time management, and ownership of learning was noticeably increased during and after their participation in the SmartLab®. These skills were mentioned as being transferable in terms of implementing these skills outside of the SmartLab® and that students were noticeably applying them in their traditional classrooms. Both facilitators were positive in all comments and praised their experiences.

Comparisons from fall 2018 to spring 2019 teacher interviews

Two interviews for both teachers/facilitators were conducted over the school year for this study. The rationale was to identify if there were any significant impacts identified over the course of the year from the perspective of the teacher in the SmartLab®. As discussed, the interviews revealed several themes that were reoccurring, but overall, there were two specific impacts that showed change that seemed from fall 2018 to spring 2019. The two changes were the role of the teacher (facilitator), and student learning.

The role of the facilitator is discussed and practiced during SmartLab® facilitator training, but until the teachers implemented it on their own it did not appear to be clear to them how their role would change. The transition from a direct instructor methodology to a

facilitator mindset or methodology, was seemingly unexpected by the teachers as evident by one of Kathy's comments in the spring 2019 interview " I guess my perspective of those twenty-first century skills is (that they have to be) much more hands-off than I thought it was going to need to be…making them search out other people or places to find the information…". She further explained the transition and struggle with the students wanting her to problem solve for them, and her resistance and how she has become more skilled at redirecting them. She explained:

> They want someone to sort of step in, so I have really had to be firmer and say no, you have to do it. (instead she will ask them) how does it look to you? What does that sound like?

In describing her transition to asking questions, instead of solving the student problems, she was describing the actual role of a facilitator and her shift into using this teaching methodology,

Donna had a similar experience she discussed in her spring 2019 interview she commented:

> When I first started, I didn't feel very comfortable at all and usually I'm very comfortable around technology, but I was scared and nervous. Now that I have had kind of a year's experience, I feel like I understand a lot more of what we are doing and how I can make it different.

She continued discussing how her mindset shifted to coming up with ideas on how to make activities in the classroom more student centered. She explained:

> We have talked about doing a DNA sample (model) with Tinkercad® (3D software), We have talked about possibly having our history teacher do Sketchup® and doing like

> a Fort Mandan (model)…or an Indian (Native American) village…or if you were gonna build a city…

The facilitators identified that there was a notable difference in the ways that they interacted with students from fall 2018 to spring 2019. The interviews data provided evidence that throughout the year there was a difference or impact on the teaching methods the teachers used with their students.

Student learning in terms of twenty first century skills was also identified as changing from the fall of 2018 to spring 2019. While learning can be expected during the school year, the facilitators were especially surprised in the differences in the level of involvement and ownership that students seemed to exhibit. In addition to the examples provided earlier, one example of the transition in learning given during Kathy's spring interview discussed in detail the shift in responsibility of the learning from teacher to student. She commented:

> The most recent project they (the students) finished in here (SmartLab®) was our solar cookers. At the beginning of the year when we were first starting, we started off with some Zometool® projects, and basic problem solving…no right or wrong kinds of things. It was a constant battle of (students saying) 'I can't do this…I can't figure this out…I can't'. Then with our solar projects they came in, got right on to the launchpad (website with curriculum), got signed in right away and started reading the project, and then they started researching and writing things down right away, and making notes with one another about who is going to bring what materials…who had things at home…what sort of things would work well as reflectors. It was the first project where I haven't had to step in and be like 'you guys need to get started'….they were all

> figuring it (themselves) and when they couldn't figure it out how they wanted to build something...they found videos to get ideas.

This example showed how students started the year out afraid to make mistakes, and by the end of the year, were confident enough to work with each other to solve problems, develop plans and strategies to complete a project. They were able to seek out resources to answer their questions and persevere through an activity without relying on the teacher to give them the answers.

Focus group analysis (Student Perspective)

Focus groups were conducted in the spring 2019. The focus groups were administered at two of the four schools included in this study. The schools were selected primarily due to their proximity and because one was a K-12 school and the other a 7-12. The rationale for completing only post focus group sessions was to provide students at least one school year to experience the SmartLab® and then to assess their perspective. The analysis was focused using the lens of potential impact due to SmartLab® implementation on students in the school.

Focus Group A

Focus group A consisted a group of sixth grade students. During the discussion, when asked about their learning using the semi-structured focus group questions (Appendix B). Students gave examples and described learning that included content but also included practicing and building twenty-first century skills with examples such as interacting with one another and with the technology in their SmartLabs®. One student stated "We get to interact instead of just textbooks You get to interact with different stuff, not textbooks. You see stuff in there more and are better about using computers." The students were asked to expand their thoughts on the effect the SmartLab® had on them, one student remarked:(The SmartLab®

purpose was) besides it is good to educate us, it's good for kids, it educates you (teachers) and that is (also) good for kids…it also helps to learn how to use computers, and programs and stuff.

The question about opportunity was intended to be focused on the SmartLab®, however when students were asked about opportunity some discussion resulted in opportunity in terms of sports participation. This led the student to reveal that although they may have an advantage in terms of sports participation, in terms of academics, larger school districts have more money and thus it is perceived that they have more opportunity. One student articulated the difference stating:

> We have more opportunities... (be)cause we can (all) play sports. We have less people. So, you don't have to do tryouts for sports. Academics though...urban has definitely more opportunities urban schools have more opportunity; they have like more money in order to do more stuff.

Opportunity and equity seemed to be addressed simultaneously in the previous comment. However, when the students were asked about how they felt about having the lab, one student said, "…well we have a lab, and they (urban schools in North Dakota) don't". This indicated a certain amount of pride that their school and its ability to provide opportunity to its students. Although there was a recognized difference in the resources available to schools, the students identified that the fact that they had the lab, somewhat leveled the playing field.

Focus Group B

Focus group B consisted of six students from grades six to twelve. Like Focus group A, themes that seemed to emerge during the analysis were like that of the facilitator interviews.

Students discussed their learning in terms of choice, decisions, and learning from mistakes, time management and problem solving. One student explained their level of autonomy and freedom of choice:

> ...freedom to do what launch (learning engagement) you can normally want to do. Just depends what your partner wants to mainly do and decide on what you should normally do together. When you get the freedom to do just like trial and error and learn from your mistakes what you're trying to do, you get to choose what you are about, and you get to choose what you do.

Another student further explained learning in terms of choice and decisions as well as the need for critical thinking because you do not have a "teacher" to prescribe exactly what you are supposed to do.

> You kind of get the idea of what you're supposed to do, but you don't have a teacher to tell you this is exactly what you're going to do, and exactly how you are going to do it, like a bunch of other classes. So, you have the freedom to work with what you want.

In terms of learning or skills, students discussed their development of teamwork skills, ability to do and learn about things that they would not normally have the access to in a regular classroom. One student articulated:

> I like that you are kind of on your own and have (to use) teamwork skills to work with somebody else and you have a chance to do stuff that you may not get a chance to learn about in just a regular class setting.

Another student reciprocated with the comment "…you get to do stuff that you wouldn't that you normally wouldn't be able to do in other classes".

Problem solving and learning from mistakes were also common topics discussed related to

learning. When asked about thoughts or feelings about the SmartLab®, one student said:

> Well I think, I like it. It's a good chance to like to explore your creativity and find new ways to solve problems that you might not have been able to easily come up with at first….it incorporates a lot of different classes.

Students also mentioned learning in terms of time management and planning. One student commented "(I like) how we do the journals, like with the SMART goal and everything, it helps, it teaches you to better find you plan, and use your SMART goals and I like that". One student summed up the learning and its tie to the opportunity that occurs in the SmartLab® in the following comment, that seemed to have the consensus of the other participants, evident by the group nodding simultaneously;

> I think it's a really good opportunity…it teaches in a wide range of things, not just between like science and technology and like math and that stuff, but it also teaches responsibility, and teamwork, and like skills you are going to need in life. Outside of learning all of the stuff that has to do with science and technology and math it will help you later in life to just kind of help build you up as a better person…like the SmartLab® can help you discover what you are good at and that you may want to pursue in a career.

Student opportunity was discussed in terms of new technology and exposure to something that the students did not previously have access to before the incorporation of the SmartLab® at their school. In describing opportunity one student explained that:

> …(SmartLab®) given us a new opportunity that we hadn't been exposed to before. It allowed us to explore new technology. I mean the 3D printer that we got that I don't

> think probably anybody in our school has, or I have not personally seen or used a 3D printer like that. And that was a really good experience...

Further discussion identified excitement for opportunities that they didn't have before, sort of tying in equity. One student explained:

> I was excited for the opportunities that it would open up for students for like different projects within the school, and what we can do now for competitions. We've used the SmartLab® for a bunch of things to help us in the school.

When asked, examples of the "things" the student referred to included yearbook, and robotics competitions.

In terms of equity, students in focus group B felt that there was equity, in fact they felt that if there was an inequity it was in their favor as they had access to community members, and with a physical gesture of their arms and hands presenting the room, provided a SmartLab®. One student commented:

> I also think that when you think about it, there are still a lot of opportunities that smaller schools, smaller like a rural schools have rather than larger schools because , then it's more if there's something that you could do out in the community, you might know a lot more community members within, where you live to help you with projects in the smart lab, where to get advice within what you're doing. If it is something with building, you can ask maybe a construction worker that works in the community that you know.

This was an interesting and revealing comment as they were not incorrect in their statement as there are currently no SmartLabs® in any urban public schools in North Dakota and currently are 14 in rural schools in the state of North Dakota. During the focus group

sessions and during the analysis of the transcripts, many of the emergent themes paralleled those of the facilitator interviews. One difference, however, was the students' focus was more specific to learning, opportunity, and equity. The discussions regarding learning included content and exposure to new things but specifically surrounded skills that the students found that they were developing such as teamwork, and time management. Student opportunity included access to new technology like 3D printing and other technologies, including materials and kits that were not previously available. Both student groups mentioned the issues of equity. Overall, the student groups did not feel as though they were at a disadvantage due to location, quite to the contrary. The students felt as though they had an advantage in terms of the smaller community and the opportunities for participation that they have as a result of smaller class sizes and more direct access to the teacher and the community. There was some mention of financial inequities, but the students qualified many of their comments by stating that they can buy more materials as they may have more money, but that they (students in their school) had more overall opportunities.

Quantitative Results

Pre and post test scores were collected using the digital literacy assessment (DLA) a validated twenty-first century skills assessment instrument. Paired T-test analysis was used to examine the results of the pre, and post DLA assessments administered to the students at the four rural schools included in this study. The assessment was given in the fall 2018 and then again in the spring 2019. The score of the assessment was not the focus of the analysis rather the change that occurred between the pre and post-test scores was what was of greatest interest to the researcher. The paired t-test analysis was utilized to investigate the research question regarding student learning if twenty-first century skills. Table 4. provides all data for the pre-

test and post-test administered to students at all four schools. Three sections were included in the table first to provide scores and analysis for all students, and then the data was divided out showing the scores from the middle school students, and elementary students as individual groups. The hypothesis identified in chapter three was that there would be a significant difference in the pre and post assessment scores, the null hypothesis was that there would be no significant difference in the pre-assessment and post-assessment scores.

Results of Paired T-tests.

When the data for all students was evaluated there was a difference in mean and standard deviation from pre-test (24.5±6.83) to post-test (27.98±7.79) with (df=59). The significance value was calculated at p=0.0001 indicating that the chance of this number occurring by chance alone (given the null hypothesis) is about .0001 (or 0.01%). The result is thus significant, and the null hypothesis can be rejected in favor of the alternative hypothesis. These data indicated that there was significance in the difference of mean scores from the pre and post assessments with the entire group.

Further analysis was conducted dividing the data into elementary, and middle school pre- and post-assessment scores (Table 5). In reference to the middle school assessment scores, the results showed that there was significance for middle school ($p=.0001$, $p < .05$). Elementary assessment scores did not meet the significance level and thus were determined to have little to no significance for elementary school ($p=0.115$, $p > .05$). These data indicate that there was a more significant impact on the middle school students that participated in the SmartLab® than the elementary students.

Table 5. *Results of Paired T-test analysis including confidence interval and p value for all students together, then for middle school students, and elementary students as separate groups.*

Group	Pre-Test			Post-Test						
	M	SD	n	M	SD	n	95% CI for Mean Difference	t	df	sig
All Students										0.000
	24.5500	6.82822	60	27.9833	7.7925	60	-5.01820, -1.84847	4.335	59	
Middle School										0.000
	21.3514	5.20265	37	25.5405	7.19797	37	-6.14731, -2.23107	4.339	36	
Elementary										0.115
	29.6957	5.98813	23	31.9130	7.20425	23	-5.01974. 0.58496	1.641	22	

* $p < .05$

Comparison of Qualitative and Quantitative Data

In concluding the analysis of these data, the research questions guiding this study were revisited looking at both the quantitative and qualitative results. In terms of determining the impact of a SmartLab® implementation on students and teachers in a rural school, impact was measured in terms of student learning, teacher perspective and student perspective. Student learning was measured in growth in twenty-first century skills as measured by the DLA, and as reported by teachers and students. The impact that SmartLab® implementation may have had on teaching methods or perspective was revealed during teacher interviews, and student perspectives were determined using focus groups.

Data including test scores and focus groups indicated that SmartLab® implementation at a rural school in North Dakota had a positive impact on student learning. Student scores on the DLA showed a significant change with an overall increase in scores over a six-month period from fall 2018 to spring 2019. Furthermore, students reported the three main impacts included learning, opportunity and equity. Learning was reported by students in terms of teamwork and time management (both twenty-first century skills).

Teachers (facilitators) reported impacts on student learning, using terms like perseverance and confidence. Furthermore, increased student opportunities had an important impact on the students as well. Support from community and administration also uncovered that there was an impact on more than just students, and teachers, but there was a potential impact on administration and on the community. The teachers were interviewed in both the fall of 2018 and the spring of 2019.

Resulting themes

The purpose of this research was to explore the impact or effect in terms of student learning and teacher methods that the implementation of a SmartLab® had on four rural schools in the state of North Dakota. This was accomplished by implementing a pre and post Digital Literacy Assessment to discover a potential change in mean scores, pre and post interviews with two facilitators, and two focus groups with students from schools with newly installed SmartLabs®.

The major findings in this chapter are organized by the following analytic categories:

1. Effect on needs
2. Impact on teaching methods
3. Increase in student opportunities
4. Impact on/from administration and community
5. Effect on student learning
6. Equity

Analytic Category 1: Effect on needs

This analytic category arose from both teacher interviews and student focus groups. Student needs were identified in several ways including limitations that existed for students (i.e. locality and funding), as well as technology access and availability. Furthermore, needs regarding staffing in reference to teacher shortage issues were also identified. For example, one teacher discussed the SmartLab® in terms of providing an alternative role for the traditional teacher. In this case, the SmartLab® environment addressed student need allowing schools to use existing staff to facilitate in the SmartLab® environments.

Analytic Category 2: Impact on teaching methods

This analytic category emerged primarily from the teacher interviews. The facilitators interviewed discussed the benefits they saw in utilizing a facilitator methodology and how they were able to recognize the impact that it had on their own problem-solving abilities. Teacher confidence and teacher methodology was impacted positively by the implementation of a SmartLab® as teachers were forced to teach outside of the box and were allowed to work in a more one-on-one basis with students. The teachers recognized the advantage of the provision of the SmartLab® curriculum to support a shift into a constructivist type of environment and the resulting ability to individualize instruction while allowing students the autonomy to make choices.

Analytic Category 3: Impact on opportunity

This analytic category arose from both teacher interviews and student focus groups. Needs and opportunities were closely related during the analysis of this data but were distinct in that needs were referred to as mostly materials, teachers, physical components (or technological access) and opportunities were access or activities that the SmartLab® was perceived to have opened or offered to the students that they would not have had otherwise.

Analytic Category 4: Impact on/from administration and community

This analytic category emerged from teacher interviews. This category rose to the surface during the interviews and is important to assess further. This category included monetary support to purchase additional materials and equipment to support the students. Initially, support by the administration and community were key in the implementation of the SmartLab® at the schools. The administration and community remained important including the continuing provision of resources, time and encouragement for the development of new

activities. Furthermore, support to provide opportunities to other teachers to provide professional development were identified as impactful.

Analytic Category 5: Effect on student learning

Student learning was addressed in each component of data collection including in the quantitative component using the pre and post assessment analysis of the DLA, teacher/facilitator interviews, and student focus groups.

The DLA revealed that overall, these data indicated that there was significance in the difference of mean scores from the pre and post assessments with the entire group. Further analysis showed that there was significance for middle school and little to no significance for elementary school when the data from the groups were separated. These data indicate that there was a more significant impact on the middle school students that participated in the SmartLab® than the elementary students.

Consideration of impact on learning as discussed by students included self-identified improvements in teamwork abilities, the power that having choice in learning activities supported their learning and had allowed for them to explore creativity and find new ways to solve problems.

Teacher interviews revealed student learning in the SmartLab®. Among the comments, student confidence, perseverance, time management, and ownership of learning were all reported as noticeably increased during and after their participation in the SmartLab®. These skills were mentioned as being transferable in terms of implementing these skills outside of the SmartLab® and that students were noticeably applying them in their traditional classrooms.

Analytic Category 6: Impact on Equity

The equity topic emerged in the student focus group sessions. Initially, equity was discussed in terms of the students feeling that they had an advantage in the fact that their school was rural. They felt that they were provided with more opportunity to participate in sports and other activities that students from other schools would have to compete to participate in. This was further qualified with the fact that they were in fact provided a SmartLab® environment, whereas the larger school districts (in North Dakota) do not currently offer to their students. There was eventually consensus in that rural schools do have somewhat of a disadvantage in that financially speaking; their funding due to enrollment is not as extensive as a school with more students.

Summary

Overall analysis of both qualitative and quantitative data indicated that the SmartLab® had a significant impact on student learning measured using the DLA as well as was reported by the teachers during teacher interviews, and self-reports from students during focus groups. Furthermore, student opportunities were increased with the implementation of a SmartLab® both in terms of access to technology and materials or software they would not have had access to otherwise. Teacher confidence and teacher methodology was impacted by the implementation of a SmartLab® as teachers were forced to work outside of the box and were allowed to work in a more one-on-one basis with students. Essentially, moving from a teacher centered to a student-centered teaching environment. Students felt that they have some advantage in terms of opportunity in rural areas, but they are aware of financial inequities that may separate the opportunities afforded to more urban school districts that have larger student populations. Overall, there was consensus among both the interviewed facilitators and the

student focus groups that the implementation of the SmartLab® in the school resulted in increased opportunities for students in their rural communities.

The final chapter of this study will provide a discussion of the findings of this research in relation to prior research on the effects of constructivist learning environments. In addition, limitations of the study, implications for theory, practice, and future research will also be discussed.

CHAPTER 5. DISCUSSION IMPLICATIONS AND RECOMMENDATIONS

Summary of Results

The purpose of this study was to explore the effect that a SmartLab® implementation had on rural schools in the state of North Dakota. Impact was measured in terms of teacher and student perspectives, and in terms of student learning that occurred over the course of the first year of implementation. There were two specific intentions in the development and conduction of this study. First, with the implementation of the SmartLab® initiative in the state, it will be important to provide data to support state leadership in decisions of potential statewide implementation. Second, there is a gap in the literature that exists on the impact of the implementation of SmartLabs®. This study provides student and teacher data on the effect the implementation and use had on their perspectives, and on teacher methodology. Next, this study contributes to the body of knowledge around the areas of student learning in relation to twenty-first century skills, social constructivism, constructivist learning environments (CLE's), and effective models of teaching. Finally, this study provides sustenance and supporting data to some of the disparities or inequities that exist in rural areas including teacher shortages, technology integration and how the SmartLab® may help to level the playing field in the state of North Dakota.

This study focused on four rural schools that had implemented a new SmartLab® in the fall of 2018. This mixed methods, quasi-experimental, phenomenological study featured semi-structured interview questions for facilitators, semi-structured focus group questions for students, and a digital literacy pre and post assessment (DLA) that was administered to students. Two facilitators from two of the four schools were interviewed in the fall of 2018 and again in the spring of 2019, and two student focus groups were conducted in the spring

2019. The DLA pre- assessment was administered in the fall of 2018 and the post assessment was administered in the spring of 2019 at all four schools to measure any notable change in test scores.

Data revealed in this study indicated that there was a significant impact on student learning as a result of SmartLab® implementation as evidenced by the focus group results, teacher interviews, as well as pre and post exam scores from the DLA. Furthermore, there were also reported effects on teaching methods as well as perceptions of increased opportunity, equity and impact on administration and community. Finally, it was reported that specified student needs were being met because of SmartLab® implementation. This chapter will focus on discussing the results of the study, providing conclusions based on the results, providing an interpretation of the findings, comparing the findings with the previous literature discussed in the literature review, identifying implications, providing recommendations for future studies, as well as limitations of this study and finally the conclusion.

Discussion of the Results

The scope of the research question for this study was to identify impact the SmartLab® had on students and teachers in terms of learning and teacher methods. As a reminder the research question was:

What is the impact of a SmartLab® implementation on students and teachers in a rural school?

- Impact is measured in terms of:
    - student learning (twenty-first century skills)
    - student and teacher perspectives on how their learning and teaching has changed.

Overall, the research goal in this study was to assess the effect on student learning in relation to

twenty-first century skills and to gain an overall understanding of student and teacher perspectives regarding the impact of the installation and use of a SmartLab® at four rural schools in North Dakota.

Ultimately, the data collected (interviews, focus groups, and pre/post DLA assessment) revealed that there was indeed an impact on learning and teaching methods. Additionally, there were other areas of impact identified. The major findings presented in chapter four were organized into the following analytic categories and aligned with the research questions referred to and aligned in Table 6.

Table 6. *Research questions aligned with analytic categories*

Research questions	Analytic categories
Student learning (twenty-first century skills)	Effect on student learning
Student and teacher perspectives on impact	Impact/effect on/from administration and community, equity, and an increase in meeting student needs and providing opportunities
Changes in teaching (teacher perspective)	Impact on teaching methods

The impacts on student learning and teacher methods were not surprising to the researcher and aligned well to provide answers the research questions, but the additional areas of impact (i.e. effect on/from administration and community, equity, and an increase in meeting student needs and providing opportunities) were somewhat unexpected. These additional areas appear outside scope, but with further review the researcher recognized their integral relationship to the study. The findings will be discussed in detail later in this chapter.

These additional areas provided guidance into future areas of study and helped to complete the full picture of the level of impact that the implementation of a SmartLab® may have on rural schools.

Conclusions Based on the Results

There were three conclusions drawn from this study of SmartLab® effect on rural schools in the state of North Dakota. First, the implementation of the SmartLab® did have a significant impact on student learning. Student learning was evidenced from all three data collection sources, the DLA, the teacher/facilitator interviews, and the student focus groups. Each of the methods provided support in the development and growth of student learning in the areas of twenty-first century skills.

The second conclusion that was drawn from this study was that the implementation and use of the SmartLab® impacted student opportunities, equity, impact on community and administration and helped meet the identified needs of the students. This data was collected from both the teacher interviews as well as the student focus groups and is discussed in more detail later in this chapter.

Finally, the third conclusion was that the implementation of the SmartLab® effected the teaching methods that teachers used in their classrooms. Data supporting this shift was reported by the teachers during the interviews and was portrayed as positive and beneficial to their students learning, and to their own problem-solving skills in the classroom. The remainder of this section will discuss each conclusion in more detail.

Conclusion 1: The implementation of a SmartLab® had a significant impact on student learning:

Each method of data collection in this study addressed the question; what was the effect of a SmartLab® implementation on student learning? This section will examine the results from teacher interviews, student responses from the focus group sessions as they relate to student learning, and the results from the pre and post DLA scores.

Teacher interviews revealed that student learning in the SmartLab® included student confidence in learning new material, perseverance when faced with different learning materials, learning how to manage their time better, and ownership over their learning. It was reported that the teachers recognized growth in their students during and after their participation in the SmartLab®. One teacher mentioned:

> The students really, at first, they were really struggling with just trying to problem solve themselves and now they're starting to see that, oh, (facilitator name) isn't really going to be helping all that much. So now they're having to learn what to do in order to do that. …and being okay with can I just go do this or do I have to ask permission to go onto the computer? And it's like, this is your room, use it. And so just that whole self-confidence has really helped…I haven't really seen a lot yet other than just their confidence building and their excitement once they get into projects.

In addition to teacher interviews, data was also collected from two student focus groups. Student learning in the SmartLab® in reference to twenty-first century skills was reinforced during focus groups specifically with mentions of teamwork, choice, creativity, and problem solving. Student focus groups revealed self-identified improvements in teamwork abilities and the power that choice had in learning activities that they chose. Students reported

that this growth in their skills supported their learning and allowed for them to be more creative in their problem-solving. One student commented, "It's a good chance to like to explore your creativity and find new ways to solve problems that you might not have been able to easily come up with at first….it incorporates a lot of different classes."

One of the IESD's (2011) key findings discussed in more detail in the literature review, they identify that, "Multidisciplinary STEM instruction (combining science, technology, engineering/design, and math) following the basic model used by SmartLab® has the potential to improve student learning and academic achievement for a broad spectrum of learners (IESD, 2011, p.2)". The mention of "lots of different classes" from the student, supports this key finding, as well as the report of incorporation and growth in the student's twenty-first century skills.

The connectedness or the sense of belonging that was mentioned by students, as they work with partners through projects, was also articulated in the data. Connectedness defined by Rovai (2002), is deeper than just interpersonal interaction, there should be a sense of belonging, and students should have active participation or engagement in the social activity to achieve this feeling of connectedness. In the SmartLab® students construct goals with partners and share with the class, this feeling of connectedness is relayed by student below:

> I like that you are kind of on your own and have (to use) teamwork skills to work with somebody else and you have a chance to do stuff that you may not get a chance to learn about in just a regular class setting.

Another student concurred with a similar comment:

> I think it's a really good opportunity…it teaches in a wide range of things, not just between like science and technology and like math and that stuff, but it also teaches

> responsibility, and teamwork, and like skills you are going to need in life. Outside of learning all of the stuff that has to do with science and technology and math it will help you later in life to just kind of help build you up as a better person…

The DLA administered in this study revealed there was significance in the difference of mean scores from the pre and post assessments with the entire group of students that were assessed. Further analysis showed that there was more significance for middle school and less significance for elementary school when the data from the groups were separated. This may be due to the sample size as there were more middle school participants (n= 37) than elementary (n= 23) or may indicate that the SmartLab® had a more significant impact on the learning of middle school students than the elementary students. This is important to report as that may be indicative of the age group that is most impacted by participation in the SmartLab®. Thus, the finding will be recommended to be further investigated in a future study.

Overall, results of the DLA indicated that the implementation of the SmartLab® had a significant impact on student learning which was corroborated by both teacher/facilitator interviews as well as by the student focus groups.

Conclusion 2: The implementation of a SmartLab® affected student opportunities, equity, administration and community and helped meet the identified needs of the students.

Opportunities

The students that participated in the focus groups and the facilitators that were interviewed provided examples of how the implementation of the SmartLab® effected their schools. They included comments regarding increased student opportunities, helping to meet

student needs as well as affecting the perceived equity of schools and engaging and impacting the community and the administration.

SmartLab® implementation increasing opportunities for students was a repeated finding from this study. One student indicated:

> SmartLab® has given us a new opportunity that we hadn't been exposed to before. It allowed us to explore new technology. I mean the 3D printer that we got that I don't think probably anybody in our school has, or I have not personally seen or used a 3D printer like that. And that was a really good experience.

Revisiting Malhoit (2005) from the literature review, it was reported that due to several issues such as geographic location, at-risk youth, and poverty, it is often more expensive to fund a rural school even with a lower population. The case can be made that rural schools do not have the same options to fund expensive technology-based initiatives. This difference further contributes to the digital divide that was identified by Resta and Laferriere (2015), as "differences between individuals, households, companies, or regions related to their access to and usage of information and communication technology" (p.745).

Similarly, the teachers interviewed corroborated the feelings of the students, and one commented on the increased opportunity.

> I'm glad that we have brought it in. I think that it's a tremendous opportunity for the different kids and the different levels…. I love that it challenges, you know, the middle school and high school kids to really get out of their comfort zone.

To make sure that all students are able to experience the same opportunities, it seems that the findings from this study suggest that SmartLab® increases opportunities for all students in the state regardless of location or school size.

Equity

As discussed, the literature review revealed issues regarding rural schools encountering technology integration disparities and teacher shortages. Kristiansen (2014) reported that rural areas can have trouble recruiting and retaining teachers. In addition, several examples including lack of access to hardware, connectivity, digital literacy skills, and the availability of technical support and access to technology skilled teachers can also cause disparity (Resta & LaFerriere, 2015). This struggle may play a role in the challenges that rural schools face in integrating technology as employing and maintaining technologically skilled teachers contributes to the previously discussed digital divide. SmartLab® implementation and the use of teachers that were not traditional choices for the technology-based environments (essentially using the resources that they have available) is one example of meeting student needs. One teacher explained the decision behind hiring her for the SmartLab®:

> Maybe due to my taking online college classes and so I'm already frequently familiar with a lot of the technology, um, and with my own kids and with the kids, you know, I feel like I have a pretty good relationship with them. So maybe understanding a lot of the technology that they're going through and that they're using. Maybe that was helpful.

As rural schools implement technology rich, student centered environments referred to in this study as SmartLabs®, options need to be available to make these opportunities equitable and available. SmartLabs® may help narrow the digital divide and provide smaller schools with technology resources, and trained facilitators to support student learning.

Administration and Community

There was mention of both impact on administration as well as impact on community, during the facilitator interviews. Both were somewhat outside the scope of this study which focused more on student and teachers, but the identified impact was important to surface as it is a potential future area of study. Examples of community impact and administration included continuing provision of resources that included time and financial support. A sense of community is created in a SmartLab® and as a result it makes sense that it could expand to the actual community, especially in a rural area. In addition, the encouragement for the development of new activities as well support from administration to provide training to other teachers and interest in the facilitators providing professional development for others was reported.

Individual Needs

This analytic category arose from both teacher interviews and student focus groups. Student needs were similar but different from both equity and opportunities discussed earlier in this chapter. However, in discussing how SmartLabs® helped to meet the student needs in this study, such as limitations that existed for students (i.e. locality and funding), as well as technology access and availability and access to high-quality teachers both equity and opportunities were increased as previously discussed implying and meeting the identified needs of the students.

Conclusion 3: The implementation of a SmartLab® effected teaching methods

The SmartLab® curriculum and environment fully supported the transition of teaching into a constructivist type of environment, referred to in literature as CLEs. In a constructivist setting, learning activity includes collaboration, cooperation, multiple perspectives, real world examples, scaffolding, self-reflection; furthermore, the instructor's roles change to coaching

guiding, mentoring, acknowledging, providing feedback, and assessing student learning (Koohang, et.al, 2009). The role the teacher plays in a CLE effectively changes from providing a teacher-centered environment and shifting it into a student-centered environment. Khan (2013) describes the facilitator as a guide, a "teacher that has to support the learners to become effective thinkers" (p.64). SmartLab® facilitators that were interviewed in this study reported this shift in methodology and discussed the benefits that were experienced.

The facilitators interviewed recognized changes in their methods such that students were provided or allowed students the autonomy to make choices in their learning. One teacher commented:

> I guess my perspective of those twenty-first century skills is (that they have to be) much more hands-off than I thought it was going to need to be…making them search out other people or places to find the information…They want someone to sort of step in, so I have really had to be firmer and say no, you have to do it. (instead she will ask them) how does it look to you? What does that sound like?

She explained how her role changed from answering student questions directly, to leading her students to find the answer, thus demonstrating the shift to more of a facilitator methodology.

It is important to mention that although transitioning from a teacher-centered to a student-centered learning environment can result in a significant learning curve for most teachers. The SmartLab® environment by design requires teachers to approach teaching in a different way than most of them have been trained, and the way they previously understood their role as teacher. Although, the teachers interviewed discussed the benefits they saw in utilizing a facilitator methodology, it was not without initial hesitation and fear. Barak (2017)

discussed “four attributes for teaching and learning in the twenty-first century: (a) adapting to frequent changes and uncertain situations, (b) collaborating and communicating in decentralized environments, (c) generating data and managing information, and (d) releasing control by encouraging exploration” (p. 283). These attributes define the characteristics of an effective SmartLab® facilitator very well. Examples of the development of these attributes can be surmised from one of the facilitators comments: She explained:

> When I first started I didn’t feel very comfortable at all and usually I’m very comfortable around technology, but I was scared and very nervous…now that I have had kind of a year’s experience, I feel I understand a lot more of what we are doing and how I can make it different.

She felt comfortable adapting and understanding how the environment worked in terms of communicating. She was also able to manage the information she had regarding the SmartLab to make changes for improvement. After practicing facilitation in the SmartLab® environment, teachers/facilitators were able to explain the value of practicing this methodology on student learning and recognize the difference that the facilitation had on their own problem-solving abilities.

> I love that it challenges, you know, the middle school and high school kids to really get out of their comfort zone. So, my feelings are that, you know, I'm really glad that it's here. I'm glad that it's pushed some of us out of our comfort zone to be a facilitator like a guide for them in their learning, you know, instead of direct instruction all the time.

Discussion and description of the teacher methodology shift provides indication of the support of a SmartLab® as a constructivist learning environment. SmartLab® usage allows schools to

move towards using social constructivism which as reported by Powell and Kalina (2009) can be defined as:

> … a highly effective method of teaching that all students can benefit from, since collaboration and social interaction are incorporated. This type of constructivism was formed after Piaget had already described his theories involving individual or cognitive constructivism. Lev Vygotsky, the founding father of social constructivism believed in social interaction and that it was an integral part of learning. Social constructivism is based on the social interactions a student in the classroom along with a personal critical thinking process (p. 243).

Constructivism is a highly effective method of teaching, and SmartLabs® as described in this study as CLEs, have been shown to provide opportunities to schools, it is important to acknowledge the relationship that exists between the two. SmartLabs® provide opportunities and the right ingredients for effective teaching to occur.

IESD (2011) summarized evidence related to the effective instructional practices of SmartLabs® and discussed three key findings in their assessment:

(a) Multidisciplinary STEM instruction (combining science, technology, engineering/design, and math) following the basic model used by SmartLab® has the potential to improve student learning and academic achievement for a broad spectrum of learners.

(b) Characteristics of the SmartLab® model are endorsed by educational researchers as supporting improved student learning and academic achievement.

(c) Characteristics of the SmartLab® model have been shown to improve students' motivation to learn and/or engagement (IESD, 2011).

Each of these findings was supported in SmartLab® environments in this study. Student learning was increased as (a) the teachers integrated technology in their classrooms in as part of the curriculum provided, (b) characteristics that include formative assessment, project-based activities, (c) active participation, student motivation, activities that are meaningful and relevant.

In addition to both student and teacher learning, facilitators reported an increased confidence from students and in themselves:

> We just did our state testing and like our NWEA testing and our science scores and our math problem solving, and the reasoning areas are up leaps and bounds over where we started and even like from winter (2018) to now (spring 2019) has been like, there's, there's huge increases in so many of my kids, like all of them showed increase, but there's, you know, progress. But some of them have just almost found like a new confidence in their ability.

Confidence can provide students and teachers/facilitators the ability to approach learning in a different way, unafraid of failure, and with able to solve problems they are faced with. Recall that Aydogdu and Selanik-Ay (2016) described successful facilitator characteristics in CLEs to include (however not all inclusive) comfort with ambiguity, ability to problem solve, willingness to learn new things, and comfort using technology. Gentry et.al (2014) identifies teacher self-efficacy on using technology and incorporating it into their classroom and posited that if teachers were more comfortable with technology their students would become better twenty-first century learners. This assessment seems to be supported by data collected from this study.

Interpretation of the Findings

The design of this study was intended to investigate the effect of the SmartLab® in rural schools in terms of learning and teaching and student and teacher perspectives. This study offers suggestive evidence that there was indeed an impact. The conclusions discussed in this chapter describe in detail, the impact of the SmartLab®. Student learning was reported to have increased as articulated by the students, and facilitators and was further corroborated using the DLA pre and post assessments. Teacher methods were positively influenced, and other impacts such as student needs, equity, opportunities, and impact on community and administration were brought to light.

SmartLabs® have a significant effect on student learning in the area of twenty-first century skills. The DLA demonstrated a significant growth in ISTE standards that were used as the measure of twenty-first century skills. Twenty-first century skills have been defined in many ways, but using DLA, and looking the ISTE standards (ISTE, n.d) skills there were increases in digital citizenship, knowledge construction, innovative designer, computational thinker, creative communicator, global collaborator, and empowered learner (See Appendix D). The hypothesis identified in chapter three was that there would be a significant difference in the pre and post assessment scores, the null hypothesis therefore was identified as no significant difference in the pre and post-assessment scores. When the pre and post assessment scores for all students were evaluated there was a difference in mean and standard deviation from pre-test (24.5±6.83) to post-test (27.98±7.79) with (df=59). The significance value was calculated at p=0.0001 indicating that the chance of this number occurring by chance alone (given the null hypothesis) is about .0001 (or 0.01%). The result was significant, and the null hypothesis was rejected in favor of the alternative hypothesis. Middle school assessment

scores showed that there was significance in growth in assessment scores ($p=.0001$, $p < .05$). Elementary assessment scores did not meet the level of significance desired in this study and thus were determined to have little to no significance for elementary school ($p=0.115$, $p > .05$). These data indicated that there was a more significant impact on the middle school students that participated in the SmartLab® than the elementary students. This finding was unexpected and potentially very important. This may indicate that there is a greater impact on middle school students than on elementary students in terms of twenty-first century skills growth by way of the SmartLab®. This may be due in part to the way elementary students are taught in comparison to middle school students (i.e. cohorts, partner activities, etc.), something that could be further investigated in a future study. With these results and using data collected from both the teacher interviews and student focus groups, it appears that correlation exists between the implementation of a SmartLab® and described growth within twenty-first century skills. The only notable change in the student school day that occurred during the period students were tested was the introduction and use of the SmartLab® on at least a weekly basis, it was reasonable to accept that the change was a result of their exposure to the SmartLab® learning environment. Overall, the implementation of a SmartLab® appears to have a positive impact on student learning.

Teacher interviews indicated that teachers were fearful at first of the shift to a different teaching method in using the SmartLab® and transitioning into a facilitator, but both realized that the shift was of benefit to not only the students, but also to themselves as learners. During the interviews, each described the characteristics of good facilitators identified through the literature that included becoming more comfortable with technology, holding more positive perceptions resulting in student skill growth, allowing time for reflection, encouraging effort,

and collaboration and monitoring and coaching performance. (Gentry et. al, 2014, Anugun, 2018, Phillips &Volker, 2014). In addition, each supported the idea of social constructivism, and implementation of CLE's by providing support for student learning by student participation in these environments.

Student focus groups provided insight into how students view the labs and the impacts that they have identified. Students reported learning in the areas of twenty-first century skills and impacts on equity and opportunities available.

The contribution that this research has in the literature, includes validation of studies in relation to students gaining or learning twenty-first century skills using a social constructivism theory of learning (Vytgotsky, 1978). Support for development of learning in constructivist learning environments (CLE's) (Li, et al., 2019; Phillips &Volker, 2014). Finally, the results provide support and validation of the effective characteristics of models of teaching identified by Joyce et al. (2015). Additionally, this research provides supporting evidence that SmartLab® implementation may alleviate some disparities or inequities that exist in rural areas including teacher shortages, and technology integration.

Results of this study were aligned with previous findings from literature discussed later in this chapter. In addition, students that participated in the SmartLab® learning environments reported the development and use of twenty-first century skills and the facilitators working the SmartLab® environments further corroborate data from the students. This study appears to support the argument that SmartLabs® have a positive impact when implemented in rural schools in the state of North Dakota.

Comparison of the Findings with Previous Literature

In comparing the findings from this study with the review of literature, it is evident that SmartLab® implementation supported student learning in terms of twenty-first century learning, support for the social constructivist learning method, as well as support regarding constructivist learning environments (CLE). Finally, effective models of teaching were also supported with the data collected in this study supporting the facilitator methodology which was reinforced in literature as being a successful to support learning. Overall, the implementation and use of the SmartLabs® provided opportunities that in some ways negated the digital divide discussed in the literature, and that existed in the state of North Dakota by increasing opportunities, providing for student needs, providing some equity across the state.

Twenty-first century skills have been acknowledged as critical to developing successful twenty-first century learners and the students' development of these skills is central in the SmartLab®. These skills defined by ISTE (n.d.) include digital citizenship, knowledge construction, innovative designer, computational thinker, creative communicator, global collaborator, and empowered learner (See Appendix D). The effect of the SmartLab® on student learning resulted in growth of their twenty-first century skills. In addition to students gaining twenty-first century skills, support for the learning theories supported in the SmartLab was also revealed.

Vygotsky (1978), stated that environments which motivate students to explore, reflect opinions, and develop their own interpretations to solve problems collaboratively is where effective learning happens which is supported by data from this study. Vygotsky incorporated a social component to constructivism and requires the contribution of a teacher and fellow

students as active participants in the student's learning path. Powell and Kalina (2009) described Vygotsky's social constructivism as:

> …a highly effective method of teaching that all students can benefit from, since collaboration and social interaction are incorporated. This type of constructivism was formed after Piaget had already described his theories involving individual or cognitive constructivism. Lev Vygotsky, the founding father of social constructivism believed in social interaction and that it was an integral part of learning. Social constructivism is based on the social interactions a student in the classroom along with a personal critical thinking process (p. 243).

Students reported their abilities to solve problems collaboratively along with their ability to reflect and explore. One student stated:

> Just depends what your partner wants to mainly do and decide on what you should normally do together. When you get the freedom to do just like trial and error and learn from your mistakes what you're trying to do, you get to choose what you are about, and you get to choose what you do.

Koohang, et.al, (2009) developed and discussed a model based on the constructivist learning theory that required three elements to be included; "design of activities, learning assessment, and instructor's roles regarding learning activities" (p.94). Furthermore, Khan (2013) described the facilitator as a guide, a "teacher that has to support the learners to become effective thinkers" (p.64). The learners should be strongly involved in setting goals and assessment should be continuous and allow for numerous perspectives. One student commented on this during the focus groups stating, "I like how we do the journals, like with the SMART goal and everything, it helps, it teaches you to better find you plan, and use your

SMART goals and I like that". Constructivist learning theories as described by Vytgotsky (1978) support the design of constructivist learning environments. CLE as discussed by Phillips and Volker (2014) include characteristics that they identified as important parts of a CLEs that include projects or activities that are based on real life, to build on real-life problem-solving skills. The learning environment should also be an open, flexible, and a practical setting (Phillips &Volker, 2014). Each of these characteristics was supported throughout the data collected in this study, and thus design of constructivist learning environments (CLE) are supported with data from this study. Characteristics that were identified as important parts of a CLEs include an open, flexible, and a practical setting and should have projects or activities that are based on real life, to build on real-life problem-solving skills (Li, et al.,2019; Phillips &Volker, 2014).

The design requirements for orchestrated immersion in complex experiences (OICE's) defined by Caine et. al. (2009) are supported in SmartLab® and meet their three critical elements of great teaching for optimal learning to occur. These critical elements include relaxed alertness, (OICE), and active processing of experiences and OICE's. OICE's are environments that offer rich experiences that fully engage student thinking. These experiences allow the students to take ownership of their learning and truly immerse themselves in the experience. They proposed that not only are students responsible for their own learning, but there are things that teachers can do (methodology and environment) to support their success. Facilitators in a SmartLab® practice relaxed alertness by supporting students and engaging them in safe, yet challenging experiences. Failure is not a bad thing, but it is seen as a learning opportunity (Caine et. al., 2009). Facilitators support OICE's in the SmartLab® as they guide learning as it is critical for students to own and immerse themselves in the process or project.

The active processing of the learning activity can be described in a SmartLab® as one type of assessment that is done. As students work through their projects with their partners, they are reflecting, documenting and making connections while facilitators observe, and through conversation assess student understanding. Both the interview data as well as focus group data from this study provided evidence that the shift to student centered methodology and the pedagogical techniques used in the SmartLab® impacted student learning.

Additionally, the facilitator of the CLE's must allow the students time for reflection and monitor and coach performance of students while encouraging effort, collaboration, and motivation from students (Phillips & Volker, 2014). During the interviews one of the facilitators commented on this role:

> They want someone to sort of step in, so I have really had to be firmer and say no, you have to do it. (instead she will ask them) how does it look to you? What does that sound like?

Mentioned earlier, one of the interviewed facilitators mentioned the change in methodology and being less hands-on and requiring students to be more responsible for their own problem solving. "I guess my perspective of those twenty-first century skills is (that they have to be) much more hands-off than I thought it was going to need to be…making them search out other people or places to find the information".

The role change from teacher to facilitator and the way that they respond to students has been impactful, not only on the teachers but also on the students and is in line with what can be found in the literature.

SmartLabs® meet all the characteristics identified by Phillips and Volker (2014) that define a CLE. SmartLabs® learners are involved in goal setting and are formatively assessed

as they go through the learning engagements. Finally, the facilitator in a SmartLab® supports students in learning by providing guidance, coaching and encouraging reflection as defined by Phillips and Volker (2014).

The results and findings from this research provided validation for not only the social constructivist learning theory (Vygotsky, 1978), and support for the design and value of CLE's, but also the effective teaching models discussed by Joyce et al. (2015). The features discussed by Joyce et al. (2015) identified the most common effective characteristics in effective teaching models. Each was discussed detail in the literature review and the characteristics can be aligned to facilitation that occurs in the SmartLab here (See Table 7.).

Table 7. *Comparison of Effective Models of Teaching and SmartLab Alignment. (Joyce, Weil & Calhoun, 2015, p. 7-9)*

Effective Characteristics of Teaching Models	SmartLab Design; Facilitation Method Alignment to Effective Models
Helping students learn how to learn	Students take ownership of their learning by formulating their own goals and documenting their learning process using journals requiring them to problem solve and seek out answers to questions.
Scaffolding for the Learning Process	The role of the teacher is shifted to that of a facilitator and their job is to guide the students and to help them overcome obstacles while providing structure and support.
Formative Assessments and Adjustments	Students are provided guidance and encouragement while the facilitator conducts formative assessment on an individual basis done through conversation and student demonstration
Twenty-first century skills	Students problem solve, collaborate, communicate, and present or demonstrate knowledge creatively,
Cultural Literacy and Global Awareness	Projects that students work through in a SmartLab® require research. Students must learn to investigate, and research not only locally, but throughout the world. Working with partners from different cultures may also allow for growth.
Collaborative and Cooperative Skills	Students must collaborate with each other and cooperate with one another to complete any/all projects they design
Creativity	Creativity is key in the SmartLab®, students must design and carry out projects that they design together.
A Constructivist Orientation	SmartLab® is a Constructivist Learning Environment (CLE). In a CLE the role of the teacher is facilitator of learning.

The findings from this study are consistent with previous research discussed in the literature review. The DLA as well as the reported learning from the students during their focus groups and the facilitators during their interviews, provided support that these characteristics of effective teaching models are represented in the SmartLab® environment and appear to be effective.

Digital Divide/Opportunities/Equity

As discussed, rural areas often face challenges to offering and utilizing the most up to date technology. A digital divide exists regarding access to hardware, connectivity, digital literacy skills, the availability of technical support and access to technologically skilled teachers (Resta & Laferriere, 2015). Findings from this study help to provide options for schools to incorporate technology-based student-centered environments at an affordable price to offer opportunities to smaller schools that may not otherwise have the resources to do so.

The findings from this study are consistent with previous research and are broadly in line with research of experts in the fields of twenty-first century skills, social constructivism, or constructivist learning methods, CLEs supported by the effective models of teaching, and demonstrate how incorporating a SmartLab® environment may have a way to, at least in part, narrow the digital divide that exists in rural schools and offer more opportunities thus increasing equity across the state.

Limitations

It is important to identify that this study was only a preliminary investigation into the impact that SmartLabs® have on rural schools. This study was conducted on a relatively small scale using only four schools, two instructors, and two student focus groups. The student

population of the schools was small, and each had a small student population (See Table 1.). Although rural schools were chosen intentionally, the school's distance from the researcher was somewhat challenging and therefore, the number of teacher interviews and student focus groups were low due to researcher proximity. Furthermore, schools were chosen based on the lab installation window, and there were only four schools in the summer of 2018 that granted the researcher permission to collect data.

The focus of this study was to identify if there was indeed an effect on student learning and perspectives and teacher methods and perspectives due to a SmartLabs® implementation. Specific causes of impact beyond the use of the lab (i.e. curriculum, teacher methods, student autonomy, increased in opportunities) were not identified nor were they explored in the student focus group or teacher interview questions. This may be an area of improvement that would have further identified what caused the effects shown. Future studies would be necessary to explore the specific causes of the impacts.

This study utilized triangulation to determine if the data from multiple sources confirmed one another. Symonds and Gorard (2010) discuss triangulation and state that "Triangulation is seen to increase validity when multiple findings either confirm or confound each other (thus reducing the chances of inappropriate generalizations)" (Symonds & Gorard, 2010, p. 129). It would have been impossible to gain full perspective of impact of the SmartLab® using only test scores, interviews, or focus groups alone. It was imperative to understand the impact from multiple angles.

In hindsight, the design of this study could have been enhanced in three ways. First, in terms of the DLA, the use of a control group would have been of great benefit to determine if there was a significant difference in pre and post assessment DLA scores found from schools

that did not implement a the SmartLab®. To conduct this study, an investigator could first implement the quantitative methods conducted in this study. This would include administering the DLA pre and post assessments to students at schools that were implementing SmartLabs® within the same year (summer), identical to the design in the current study. The researcher would then need to administer the same assessment to students in schools that were equivalent in size in comparative regional areas. This would provide a control group from which to determine if the growth could be correlated to the implementation of the SmartLab®.

Second, interviewing additional facilitators to gain a more in-depth understanding would have further validated the findings of this study, there were two additional facilitators that could have been interviewed for this study, but due to the remote locations of the schools, and the time constraints, only two of the four were interviewed. Additional interviews could further strengthen the findings that have been reported.

Finally, conducting additional focus groups sessions with students to further explore the identified themes would have provided a more detailed account of the student experience. Only two focus groups were conducted again due to the remote locations and time constraints of the investigator. To alleviate both, a survey could have been developed to ask students similar questions that were asked during the focus groups.

The researcher's role in the installation of SmartLabs® in the state of North Dakota and the training of other facilitators in these environments over the past several years could be perceived as a potential for bias. All attempts to remain objective were made; the researcher was cognizant of reactions to answers provided for questions from both facilitator interviews as well as student focus groups. During the introductions of both interviews and focus groups and in the consent forms for both interviews and focus groups the value in open honest answers

whether supportive or non-supportive of the SmartLab® were desired. During analysis meaning regarding answers to questions was not assumed and the researcher used only responses and notes made throughout the data collection events to categorize data. Thus, the researcher was cognizant of the bias that could occur, and the possibility of bias existed due to the researchers working relationship with the schools, and the researcher's role in the SmartLab® initiative implementation and should be revealed and reported as a potential limitation.

Implications of the Study

This research found that the implementation of a SmartLab had a significant effect on student learning, and on the methods that teachers use in the classroom. This study also found other identified areas of impact due to SmartLab® implementation that included an increase in student opportunities, perceived equity, community and administration, and helping to meet the identified needs of the students. The majority of North Dakota is considered rural, the schools and student population included in this study were meant to represent this population in the state. With that understanding and intention, the sample size was somewhat small and therefore an increase in the sample size would be beneficial for future studies.

This study has supported the classification of a SmartLab® as a CLE, which by design focuses on the use of the social constructivist learning theory. The benefits of CLE's are well documented in literature, as is the value of the social constructivist learning theories as described by Vytgotsky (1978). Data collected and analyzed in this study report significant positive impact on student learning and teacher methods, which provides support for the benefits of constructivist learning environments as well as supports the use of the social constructivist learning theory.

This study was meant to determine what, if any, the impact or effect a SmartLab® implementation would have on student learning and teaching methods in rural schools in North Dakota. There have been several studies looking at CLEs in general, but none that were specifically focused on SmartLabs®. This study serves to fill a gap in literature that exists regarding the effects of a SmartLab® implementation. Over the years hundreds to thousands of SmartLabs® have been installed across the country, there are currently nineteen in the state of North Dakota with a proposed state funded implementation for the installation of one in every district in the state. There has been a great interest in SmartLab environments and their implementation in rural schools through word of mouth and district to district observation. Leaders are recognizing the value and are in need of data to support this potential plan for SmartLab installations. Responsible leaders make data driven decisions. A statewide implementation of SmartLabs® without a study that demonstrated value would be irresponsible. This study provides evidence of impact and value of a SmartLab implementation in rural schools in the state of North Dakota.

Recommendations for Future Research

Several possibilities and recommendations for future studies have emerged from the completion of this study. First, based on the data collected from this study, an additional study to determine what characteristics of the SmartLab® had the most impact would be of great benefit. Future research on SmartLab® environments would benefit from directly focusing on one characteristic at a time which based on the results of this study may include access to the materials/curriculum, teacher training in constructivist methodology, technology integration, access to new technology, increased opportunities, or student autonomy. The results of this

study may help to identify what part of the SmartLab® had the most prominent effect on student learning.

Next, as discussed in the limitations section of this chapter, an additional study that replicates this study, with the addition of a control group to further validate the findings from this study could also be of great benefit.

Furthermore, the relationship between SmartLabs and academic learning would also be a future area of study that could be of great benefit. GÖZÜYEŞİL, E., & DİKİCİ (2014), reported that those students in environments that supported twenty-first century learning performed better academically. Although this study did not measure specific academic scores outside of the CSA, future studies could be conducted to validate the finding regarding the learning of twenty-first century skills. In addition, one of the key findings by IESD (2011) indicated that "Characteristics of the SmartLab model are endorsed by educational researchers as supporting improved student learning and academic achievement" (IESD, 2011, p.3). A study to measure academic learning could be achieved by using student standardized test scores. This could be conducted as a longitudinal study measuring the impact over an extended period and could provide a more complete picture of the effect that SmartLabs® are having on student learning.

This study discussed several issues that plague rural schools including teacher shortages, difficulty in technology integration, and limited resources due to funding. Data from this study, has suggested that by the implementation of SmartLabs® schools have been provided some support in these areas. Determining the level of help or overall effect of SmartLabs® in the support of these specific topics could be of benefit. For example, does the installation of a SmartLab® in a rural school in North Dakota result in teacher retention?

Furthermore, the perception of ease in technology integration in rural schools could be an area to investigate further.

Finally, repeating this study using the same instruments including the DLA, and interview and focus group protocols, with a larger population for each group would be beneficial in verifying and validating the findings from this study.

Conclusions

This mixed methods quasi-experimental phenomenological study investigated the impact that a SmartLab® implementation had on four rural schools in the state of North Dakota. This study looked at student learning in terms of twenty-first century skills, teacher and student perspectives in terms of student learning as well as teacher perspectives on the impact of the SmartLab® on their own teaching methods. A review of the literature focused on the constructivist learning theory, characteristics of successful teaching models, CLEs, constructivist teacher methods, and student learning in terms of twenty-first century skills.

In addition to the provision of some direction for future research, this study has made three additional contributions to the literature. The first contribution was the support and validation of the literature regarding the value of CLE's and their influence on student learning. Second, this study has contributed to the literature regarding the constructivist teaching methodology and support of the teaching of twenty-first century skills to prepare students for the future as students in classrooms where the teachers are facilitators of learning show growth in learning. Finally, this research has provided some key ideas that suggest that there are at least six areas of impact that were affected by the implementation of a SmartLab®, most of which were referenced in the literature review.

The goal of this study was to assess the impact on student learning in terms of twenty-

first century skills, and to gain an overall understanding of student and teacher perspectives regarding the impact of the installation and use of a SmartLab® at four rural schools in North Dakota. There was a positive impact in response to each part of the research question. There was a significant impact on student learning as a result of the SmartLab® implementation, there was a positive impact on teacher methodology, and there was a reported impact on student learning and confidence. The results from this study imply that the implementation increase student opportunities and provides equity and helps to fulfill identified student needs. The results of this study are significant for the state of North Dakota and could influence decisions as to statewide implementation of a the SmartLab® program and may impact students, teachers, schools, districts, and potentially the whole state.

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APPENDIX A. FACILITATOR INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

Participant Selection:

- SmartLab® trained facilitators from a school that has installed a lab in the summer of 2018.

Interview Protocol

Project: The Impact of a SmartLab® Implementation on Rural Schools in North Dakota
Time of Interview:
Date:
Place:
Interviewer: Tonya Greywind
Interviewee:
Position of interviewee:

Brief Description of Project:

The purpose of this interview will be to explore the perceptions, impressions, and understanding of the SmartLab® faculty members from 4-5 school districts that have had labs installed in the summer of 2018. Participants will have been trained in the lab. The selection of the participating is based on those that have been trained in the lab and it is their primary responsibility to "teach" in the lab. The data will consist of two semi-structured interviews (per school), and two one-hour observations (per school). The observations will be unstructured and conducted primarily to offer context to discussions during the interviews and will potentially allow for recognition of differences in student and teacher interactions in from fall 2018 to spring 2019. A primary focus will be on teacher experiences in the SmartLab® and the impact it has had on them, and their students. It is the hope of the researcher that this study will offer insights into the thoughts and feelings of lab facilitators and how it affects their teaching methodology and perceptions.

Central Question:
What is your understanding, experience, perceptions, and impressions of the SmartLab® at your school? How has it impacted your teaching?

Questions:

Understanding/Involvement:

a. Have you been asked or approached by any interested staff or faculty member in terms of learning more about the SmartLab®?

Experience/Perceptions:

2. Would you say that your experience in 21st century /teaching and learning has changed?

3. Describe your personal *experience* in the SmartLab®?

    a. How much time have you spent in the lab with your students?

    b. Have you noticed any differences in your students learning that you would credit to their participation the lab?

    c. Has your experience in the SmartLab® changed anything about how you teach?

Impact/Impressions:

4. In your opinion, what has been the overall *impact* of the SmartLab® on students and staff?
    a. Have there been any noticeable changes in other classrooms or teachers that you would attribute to the SmartLab®?

    b. Changes in your training?

    c. Has the installation of the SmartLab® created any changes in relationships at your school?

    d. Overall feelings regarding the lab?

THANKS

*Be sure to thank the participant. Also, be sure to advise of the confidentially of the responses.

APPENDIX B. FOCUS GROUP PROTOCOL

Emphasize that there are no right or wrong answers, only differing points of view
We're recording:

- One person speaking at a time
- We're on a first name basis
- You don't need to agree with others, but you must listen respectfully as others share their views

Script:
Good afternoon and welcome. Thanks for taking the time to join us to talk about SmartLab®. You may already know, but my name is Tonya Greywind and I am from the North Dakota Center for Distance Education. I am having discussions like this with several groups around the state to find out your thoughts on the SmartLab®.
You were invited because you have participated in SmartLab®. Your feedback is very valuable. There are no wrong answers but rather differing points of view. Please feel free to share your point of view even if it differs from what others have said. Keep in mind that we're just as interested in negative comments as positive comments, and at times the negative comments are the most helpful. You've probably My computer, I am recording the session because I don't want to miss any of your comments. People often say very helpful things in these discussions, and I can't write fast enough to get them all down. We will be on a first name basis today, and I won't use any names in reports, and I am the only one that will hear this recording. You may be assured of complete confidentiality.

1. What did you think of the SmartLab® program?

2. What do you like best about the SmartLab® environment?

3. What do you like least about the SmartLab® environment?

4. How has working in the SmartLab® affected you in other classes?

5. Think back to when the lab was first installed, how did you feel about it being a part of your school?

6. How have your feelings changed since you first encountered the SmartLab®?

7. When you compare urban schools to rural schools in the state if North Dakota to one another;

8. Do you feel like there are equal opportunities provided to students?

9. In terms of the previous question regarding equity, how does the SmartLab® impact your responses?

10. Suppose that you had one minute to talk to the governor of North Dakota about your SmartLab® and the impact it has had on you or your school? What would you say?

11. Any further comments? Or am I missing anything important?

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APPENDIX C. FACILITATOR COMPETENCIES

ND SmartLab Facilitator Competency Checklist

Facilitator in Training: _____

Date of Training Completion: _____

NDCDE Trainer(s): _____

Competency	Demonstrates Proficiency	Developing Proficiency	Did Not Observe	Recommendations for future practice.
Standard 1: The learner can demonstrate a basic level of tech savviness.				
Benchmark 1.1: The learner demonstrates how to log into the computer, create, and manage student logins.				
Benchmark 1.2: The learner demonstrates an ability to update software and hardware on a regular basis.				
Benchmark 1.3: The learner demonstrates how to access learning launchers and can log in as an administrator to edit visible learning launchers.				
Benchmark 1.4: The learner displays a moderate to high level of comfort around technology and works to solve technology related problems without hesitation.				
Benchmark 1.5: The learner demonstrates an ability to present small bits of information to students via an overhead projector or master computer.				
Benchmark 1.6: The learner demonstrates basic skills needed to freeze and thaw computers with deep freeze.				
Standard 2: The learner displays personal characteristics that convey a calm, organized demeanor that supports a student centered methodology in the SmartLab.				

Competency	Demonstrates Proficiency	Developing Proficiency	Did Not Observe	Recommendations for future practice.
Benchmark 2.2: The learner displays a calm problem solving demeanor as problems and questions arise in the SmartLab that the learner may not know the answer to.				
Benchmark 2.3: The learner shows the ability to tolerate ambiguity and adaptability to changing conditions.				
Benchmark 2.4: The learner demonstrates basic classroom management skills but allows a certain "managed" level of chaos that supports student learning.				
Benchmark 2.5: The learner shows a willingness to help students and typically defaults to encouragement not criticism.				
Benchmark 2.6: The learner demonstrates basic organizational and planning skills.				
Standard 3: The learner is willing and able to successfully communicate through multiple mediums with students, parents, staff, and administration.				
Benchmark 3.1: The learner is able to recognize and utilize non-verbal cues.				
Benchmark 3.2: The learner shows multiple ways that they plan to communicate student work with parents and staff.				
Benchmark 3.3: The learner can define and demonstrate the necessary skills and steps needed in building positive relationships with kids.				
Benchmark 3.4: The learner models a plan for handling visitors both local and non-local in the SmartLab.				
Standard 4: The learner can define and demonstrate how the SmartLabs student centered methodology to learning is vital to its success.				

Competency	Demonstrates Proficiency	Developing Proficiency	Did Not Observe	Recommendations for future practice.
Benchmark 4.1: The learner can explain the difference between a student centered and teacher centered approach to instruction.				
Benchmark 4.2: The learner can show how assessments are completed in the SmartLab using student projects.				
Benchmark 4.3: The learner can define and demonstrate the need for the practice of student reflection at the end of SmartLab sessions.				
Benchmark 4.4: The learner can demonstrate how the four 21st Century skills of critical thinking, communication, collaboration, and creativity are taught in the SmartLab.				
Benchmark 4.5: The learner demonstrates how to interact with students in the lab that have questions by facilitating to help the student solve the question for themselves.				
Benchmark 4.6: The learner explains why lecture should be used sparingly in the SmartLab.				
Standard 5: The learner shows the ability, willingness, and knowledge to contact North Dakota's Center for Distance Education and or Creative Learning Systems to help solve SmartLab related technical problems.				
Benchmark 5.1: The learner can define who to contact at NDCDE for specific problems and how to contact them.				
Benchmark 5.2: The learner can define who to contact at CLS for specific problems and how to contact them.				
Benchmark 5.3: The learner can explain the types of problems to contact NDCDE about and the types of problems to contact CLS about.				
Benchmark 5.4: The learner can define what sorts of problems they should be able to solve on their own.				

APPENDIX D. ISTE STANDARDS AND COMPETENCIES

ISTE standards described with student competencies (Learning.com, 2018)

Empowered Learner	Students leverage technology to take an active role in choosing, achieving and demonstrating competency in their learning goals, informed by the learning sciences.
Digital Citizen	Students recognize the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, and they act and model in ways that are safe, legal and ethical.
Knowledge Constructor	Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others.
Innovative Designer	Students use a variety of technologies within a design process to identify and solve problems by creating new, useful or imaginative solutions.
Computational Thinker	Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions.
Creative Communicator	Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals.
Global Collaborator	Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally.